NARROW GAUGE RAILWAYS.

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BY

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LONDON:
E. & F. N. SPON, 48, CHARING CROSS.
1871.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.

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PREFACE.

Since writing my Paper on the Festiniog Line and Narrow Gauge Railways, read before the Honourable Commissioners from Russia, India, and other countries, at Tanybwlch, in February, 1870, at which His Grace the Duke of Sutherland presided, questions have been raised as to the largely reduced cost in construction of such lines, as compared with those of the ordinary gauge; it was therefore desirable that some further information illustrative of such statements therein contained be made, together with diagram sections of works that will embrace a clearer definition of what I wished to convey. Having been advised to read any further statistics on the subject at the East India Association, I determined to do myself the honour of calling upon Sir Bartle Frere and Mr. Thornton, to request their kind permission to read a Paper on Narrow Gauge Railways at that Association, to which I received their warm approbation. I more fully appreciate the honour conferred, as Mr. Thornton and other gentlemen in high authority in Government administration in connection with Railways and Public Works in India, visited the Festiniog 2 ft. gauge Railway, with a view of witnessing the utility and capabilities of conducting the traffic on a line of so small a gauge and for determining the gauge of future lines in India. In the interim, I received a letter from the Secretary of

the East India Association, informing me that the narrow gauge for India had been decided upon by the Government, and that all controversy as to gauge was at an end, and that the gauge of future lines in that country was fixed to be 3 ft. 3 in. Under these circumstances, it was apparent that my reading the Paper at the East India Association would be an inconsistent course to adopt; however, in consequence of the very great interest entertained in the subject by railway and other scientific men in all parts of the world, I determined, through the advice of my friends, to publish it. It will be well that the following copy of the Paper read before the Honourable Commissions; and of experiments made on the Festiniog Railway by them on the 11th and 12th of February, 1870; and of my Paper read at the Inventors' Institute; also of various subsequent experiments before the Indian Commission, &c., together with copies of articles in 'The Times' paper, letters and abstracts from some of the scientific publications, be also submitted.

NARROW GAUGE RAILWAYS.

COPY OF PAPER READ AT THE "INVENTORS' INSTITUTE."

By C. E. SPOONER.

Reprinted from the 'Scientific Review,' 1865.

The object of the paper which I have the honour to submit to the members of this valuable Institute is to discuss the subject of narrow gauge railways, explaining the necessity of their general use, their economy in construction, their utility in certain districts as "feeders" to through lines, and their adaptation to passenger as well as to general traffic.

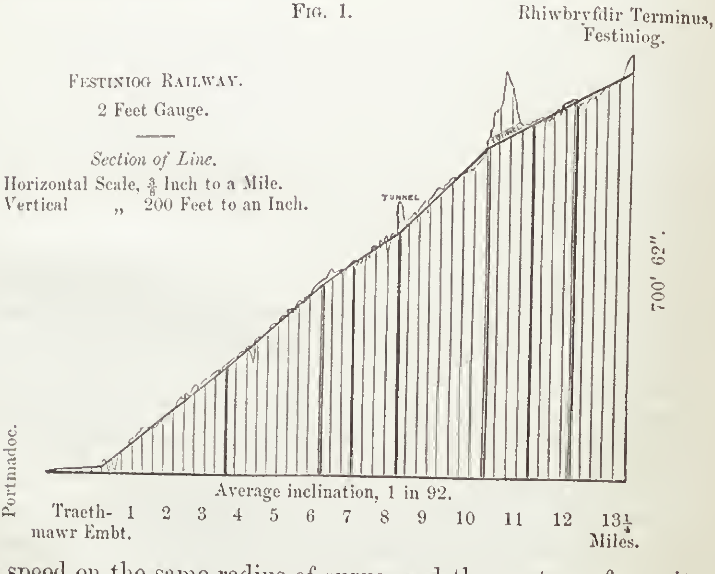
The introduction of railways on a narrow gauge, and worked by locomotive power, is a growing necessity for opening districts where lines connecting one through line with another are either impracticable or would be so costly as not to justify the outlay required for their construction; also in mountainous and mineral districts, where their application would be the greatest possible boon to the public, and the means of giving to districts railway communication that, on the parliamentary gauge, would be too expensive ever to be made. It is in these latter districts that their application would be especially useful, inasmuch as with narrow gauge lines of 2 ft. 6 in., or from that to 2 ft. 9 in., curves of three or four chains radii can with facility be made, and by this means tunnels, viaducts, and heavy earthworks are avoided which on the broader gauge would be inevitable; and, at the same time, there is no necessity, on short lines of this kind, for any very great amount of speed, which is imperative on "through lines."

It is found that the various gauges of railways in different parts of the world are:—In the United States of America, 6 ft.

and 4 ft. 8½ in.; South America, 5 ft. 3 in.; Central America, 4 ft. 8½ in.; Austria, 4 ft. 8½ in.; Australia, 5 ft. 3 in. and 4 ft. 8½ in.; Belgium, 3 ft. 8 in. and 4 ft. 8½ in.; Canada, 5 ft. 6 in. and 4 ft. 8½ in.; Cape of Good Hope, 4 ft. 8½ in.; Denmark, 4 ft. 8½ in.; England, 7 ft., 4 ft. 8½ in., and 2 ft.; Egypt, 4 ft. 8½ in.; France, 4 ft. 8½ in. and 3 ft. 4 in.; Ireland, 5 ft. 3 in.; Italy, 4 ft. 8½ in.; India, 5 ft. 6 in. and 4 ft.; New South Wales, 4 ft. 8½ in.; Norway, 3 ft. 6 in. and 4 ft. 8½ in.; Prussia, 4 ft. 8½ in.; Portugal, 5 ft. 6 in.; Russia, 5 ft.; Sardinia, 4 ft. 11½ in.; Spain, 5 ft. 5 13/16 in.; Scotland, 4 ft. 8½ in.; Switzerland, 4 ft. 8½ in.; Sweden, 3 ft. 6 in. and 4 ft. 8½ in.

These sections (Figs. 1 and 2) show the Festiniog Railway on a 2 ft. gauge, and a corresponding or comparative section of a line which if made to and from the terminals for the same traffic on the ordinary gauge of 4 ft. 8½ in., such section having been carefully taken, with maximum curves suitable for that gauge, for the

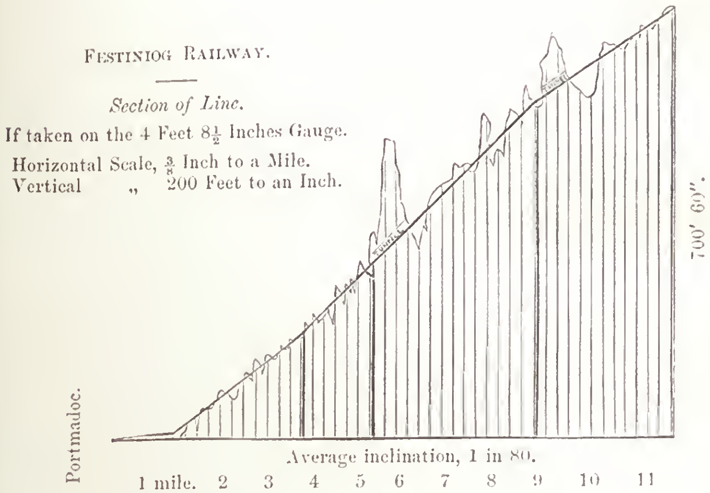
FIG. 1.



like speed on the same radius of curve, and the centres of gravity of the locomotive and carriages of one gauge brought to the same as that of the other, and with proportionate weight of train, the same speed might be attained with equal safety. For instance, as the radius of 2½ chains curve from A to B (Fig. 3) on gauge of 2 ft. 6 in., with wheel base of 5 ft. from centre to centre of axle

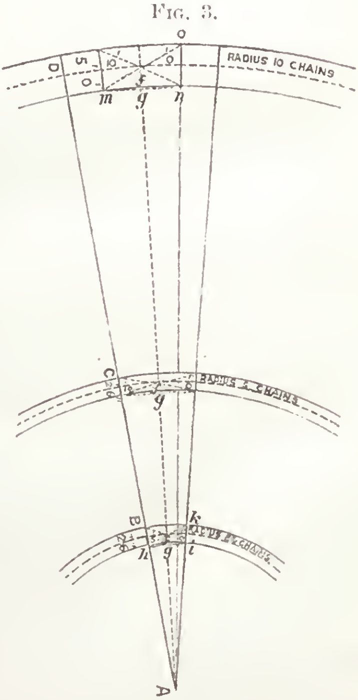
of carriages, is to A C on radius of 5 chains on the same gauge, with 10 ft. from centre to centre of axles, so is A B radius of

Fig. 2. Rhiwbryfdir Terminus, Festiniog.



$2\frac{1}{2}$ chains on 2 ft. 6 in. gauge to radius A D of 10 chains of 5 ft. gauge and 10 ft. centres, as per parallel dotted lines shown by the versed sine fg on $2\frac{1}{2}$ chains radius of the chord hi, equal to fg of chord mn on 10 chains radius, or half that of fg on the radius of 5 chains and 10 ft. centres. It would appear that with a succession of small radii curves, a train might be running on three curves at one time, and that in consequence a relaxation of speed would be incurred, caused by the drag binding the wheel flanges against the inner rail of curves, but the results of experiments made give little or no perceptible difference in the speed on passing over such curves.

Fig. 3.



For practical purposes it is not necessary that an exact proportionate size of carriages and trucks should be maintained; it is sufficient if they are about one-fourth the weight and carry one-fourth the bulk or load of those on a 5 ft. gauge, care being taken that the centre of gravity be brought as low as possible, and that the maximum speed be limited to a less rate than that of a 5 ft. gauge. Very heavy loads are drawn with locomotives of small diameter driving wheels connected, and from their shortness a weighted train is easily started.

Fig. 4 represents the same centre of gravity of carriages or trucks for 2 ft. 6 in. gauge and 5 ft. gauge, as per equilateral

Fig. 4.

angles marked *a b c*. On the Festiniog Railway, of 2 ft. gauge, the passenger carriages are arranged as per dotted lines, which gives an excessive overhanging and rather awkward appearance.

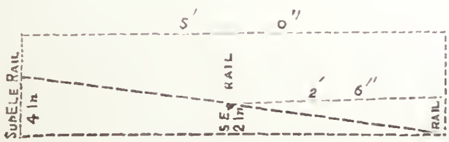
With locomotive engines of 2½ ft. driving wheels for a 2 ft. 6 in. gauge, which, as compared with 7½ ft. driving wheels, or (as 7½ ft. circumference is to 23) with three revolutions to one, it will appear there would be three times the friction on the pistons, piston-slides, and the tyres of the wheels; but, practically, this is not the case, as the friction caused by the greater weight of the engine of the broader gauge is in fact counterbalanced; also the wear and tear of the rails and line for the same reason is greater.

Fig. 5 represents the rectangular wheel-base on curves of 2½ chains, 5 chains, and 10 chains radii—say for maximum curve of 2 ft. 6 in. gauge and 5 ft. gauge—with a given velocity, and the super-elevation of outer rail of 2 ft. 6 in. gauge and 5 ft. gauge.

The Festiniog Railway was made under an Act of Parliament passed in 1832, and built to a gauge of 2 ft. The traffic was,

until within the last eighteen months, worked with horses. For many years it was the wish of my father (the Company's late engineer) to use steam power, but he met with little encouragement as to the practicability of constructing suitable locomotive engines for so small a gauge. It was only from the constantly increasing traffic, and the necessity of affording the country passenger accommodation, that it became essential to take the steps which led to this successful issue. Careful measures were entere upon for this purpose, which resulted in the construction of two trial engines, made by Messrs. England, and the experiment proved so successful that the Company was enabled to accomplish the end they had so long desired. At the present time they work the traffic with these engines and two spare ones, and they have also made their line suitable for passenger traffic. The Government Inspector, Captain Tyler, R.E., who, with his usual ability and energy of purpose, tested this little line and the locomotives to

Fig. 5.



the utmost, complimented the Company on the efficient state of their railway. In his report to the Board of Trade some additional appliances were required, which having been made, the Company obtained the sanction of the Board to open their line for passengers. This line of 13¼ miles in length (see section), has a difference in level between the termini of 700 ft., having a continuous average grade of 1 in 92 for 12¼ miles of its length. The exertive power is one way only—from Portmadoc (the great slate depôt for shipment) to the upper terminus. The down traffic is entirely by gravity. During the last eighteen months the engines have run over a distance of 60,000 miles without leaving the rails. The locomotives are made to the same centre of gravity as those used on the Great Western Railway; three of these weigh 7½ tons each, and one 8 tons in steam. The engine has two pair of wheels coupled, of 2 ft. diameter; cylinders 8 in. in diameter, with a length of stroke of 12 in., and having a

maximum working pressure of 200 lbs. to the square inch. The passenger carriages are 6 ft. 6 in. high in the centre, 6 ft. 3 in. wide, with 1 ft. 6 in. diameter of wheels, and 4 ft. 6 in. centres from wheel to wheel, having a cushioned-back partition inside from end to end. The seats are brought immediately over the wheels, and passengers sit back to back, the arrangement being such as to bring the centre of gravity as low as possible. The floors of carriages are 8 in. above the rails, consequently no platforms at stations are necessary, and passengers get in through doors at both sides. Open cars on the same principle, with aprons for bad weather and straps in fair weather, are also in use. It is an interesting and novel sight to see one of these little engines, with a train 120 yards in length, running up gradients of from 1 in 70 to 1 in 180, at a speed of about 12 miles an hour, round curves varying from 2 to 30 chains radius, hugging the hill-sides, through some of the most beautiful scenery in North Wales. The engine in its passage is out of sight when going through some of the cuttings, and the train occasionally on three curves at one time.

Where there is a limited amount of traffic, and no necessity to use great power to do that traffic, nor to execute the heavy and costly works required in the construction of the broader-gauged line, why should such expenses be unnecessarily incurred; or, in other words, why make use of a horse to do the work of a pony? While so much discussion has taken place at various times as to break of gauge, and on the subject of adopting one uniform gauge for through lines in this country, it is strange that the policy of lateral branches on a small gauge has either been considered impracticable, or altogether ignored. In maritime locomotion will be seen in daily use vessels, from the small river boat to that of a line-of-battle ship, varying in size and power with the required traffic, local position, the size of rivers, lakes, channels, and seas, as under the peculiar circumstances is found most applicable and beneficial. The question then arises, Why not make the same useful and reasonable practice applicable in our railway system? Captain Tyler remarks, in his paper read at the Institute of Civil Engineers "On the Festiniog Railway," "The employment of locomotive engines on this little railway, and its opening for passenger traffic, were not only highly interesting

experiments, but very likely to be followed by important results. Although there were still, doubtless, numerous districts where railways on a gauge of 4 ft. 8½ in. might be profitably made, yet there were also many others in which lines of cheaper construction were required. With a narrow gauge, lighter rails and sleepers, less ballast, and cheaper works generally might be adopted; sharper curves might be laid down, very heavy gradients, particularly in mountainous regions, might be more easily avoided, and lighter engines, with lighter vehicles, might be made to do all the work where high speed was not demanded, and where the traffic was not heavy.

"It was however illegal at present to construct any passenger lines in Great Britain on a narrower gauge than 4 ft. 8½ in., or in Ireland than 5 ft. 3 in.; consequently it would appear to be desirable to obtain the repeal, or at least a modification, of the provisions of the Act 9 and 10 Vict., cap. 87, which regulated the width of the gauge of the passenger lines, as there was now an increasing demand for railways of a minor class. Many coal and mineral lines on a less gauge than 4 ft. 8½ in. were in use, and others were projected with ultimate views of passenger traffic, and it would be advantageous if some narrow gauge were recognized."

In his report "On the Festiniog Railway" to the Board of Trade, he stated, "The adoption of the locomotive power upon this little line is very important, and has evidently been a very successful experiment. The cheapness with which such a line can be constructed, the quantity of work that can be economically performed upon it, and the safety with which the trains run over it, render it an example which will undoubtedly be followed sooner or later in this country, in India, and in the Colonies, where it is desirable to form cheap lines for small traffic, or as a commencement in developing the resources of a new country."

It may be argued that a break of gauge would incur a change of passengers and luggage at junction stations; this is true, but is it not the common practice on all lines, even where there are the same interest and same gauge? And further, it may be said that heavy mineral traffic and mercantile goods would have to be shifted from the trucks of the one to those of the other, to the damage and loss to the public or risk to the railway companies. As to minerals and goods, it is true they would have to be shifted, and

there would be the cost of so doing; but the raw material cannot receive any very great injury in the operation. As regards mercantile goods, it is the common practice to detain trucks at the different stations for the delivery of miscellaneous goods, and trucks are often detained in order to fill or make up a load; but if none of these answers could be brought to bear in extenuation, the disadvantages are but insignificant when compared with the large benefits that would be secured to the public by the construction of narrow gauge lines in peculiar districts, and as feeders to the main or through lines, and which it is obvious will be followed by a general increase of traffic spread over all main lines in the United Kingdom.

As to consumption of fuel, it is found that between 17 and 18 cwt. is used daily on the Festiniog Railway, with trains running at an average speed of eleven miles an hour, which, on the weight of trains conveyed during the year of goods and passengers (including weight of carriages and trucks) taken *up* the line from Portmadoc to the quarry terminals, on 56,875 tons over ascending grades, the whole distance, including shunting at stations, was three-quarters of a pound per ton per mile; or, if taken on the traffic of slates, goods, and passengers, of 81,400 tons, the fuel consumed was half a pound per ton per mile.

It would be advisable that a somewhat wider gauge should be given than 2 ft., so as to have a greater width of framing for boiler, fire, and smoke box, and to be two or three inches higher from the rails than the engines used on the Festiniog Railway, which are somewhat confined for room, and that the engines should be made with three pairs of wheels; also that the trailing wheels should be of broad tyres, without flanges for the purpose of steadying the engine. By this arrangement ample room would be given for the connecting and eccentric rods; it would facilitate lubrication, and ensure a very perfect and powerful locomotive. In conclusion, I believe, from observations made, that a 2 ft. 6 in., or a 2 ft. 9 in. gauge, would be one most suited for the description of lines here set forth.

In respect to the above paper, I wish to modify the views therein expressed in three particulars. Firstly, in reference to

rolling stock in paragraph page 4; secondly, as to the capacity of narrow gauge lines, in paragraph page 6, beginning with "where there is a limited amount of traffic," &c.; and thirdly, to the description of locomotive engines recommended in page 8. As regards the first, I subsequently made several experiments with trains on the Festiniog Railway, at speeds varying from twenty to thirty miles an hour over parts of the line, and at twenty miles an hour over the sharpest curves, from which it was evident that rolling stock (goods, trucks, &c.) of greater carrying capacity could be used with safety and economy at comparatively high velocities. The rolling stock since then has been constructed accordingly. With regard to the second, I wish to withdraw the words "limited amount of traffic," as at that time I was unacquainted with the principle of the Fairlie engine, or in fact that such an engine was in existence. From experience had on the Festiniog Railway with the "Little Wonder," I believe the capabilities of the 2 ft. 6 in. gauge, whether a single or double line, worked with the Fairlie engines will be nearly equal to that of the 4 ft. $8\frac{1}{2}$ in. gauge worked with the ordinary engines, and very superior as regards the amount of paying to unpaying weight carried, because a ton can be carried with about half to two-thirds the dead weight. At the same time I am satisfied that it is practicable to construct engines on the Fairlie principle applicable for 2 ft. 6 in. gauge lines that will exceed in power any six-wheeled locomotive on the 4 ft. $8\frac{1}{2}$ in. gauge.

With regard to the third, it will be at once understood that I recommended the engine described, because I found great want in the four-wheeled engines we were working, and desired to adopt some plan to prevent that violent oscillation which I found so destructive to the engine rails and works generally. In the absence of anything better, I suggested an additional pair of wheels with broad tyres, but without flanges being placed under the foot-plate end of the engine to support it, which, while permitting it to pass freely round the curves, would have prevented a good deal of the bumping and consequent injury.

The Fairlie engine embraces all the desiderata I then, as now, deemed necessary for economically working railways.

THE FESTINIOG RAILWAY.

Reprinted from 'Engineering,' September 24, 1869.

"More than four years ago Captain Tyler, R.E., gave to the Institution of Civil Engineers a very complete and exceedingly interesting account of the little 2 ft. gauge, single-line railway extending from Portmadoc to Festiniog and Dinas, in Merionethshire. Precise and circumstantial as was this account, however, none who have not seen the line itself can possibly form an adequate notion of its extraordinary features. It may seem easy enough to imagine a 2 ft. gauge, or even easier to *see* it by laying down a couple of railway or other bars, or even a couple of light timber scantlings two feet apart. But these bars or scantlings will not even then look like a practicable railway, and still less so if they have not their corresponding concomitants of lilliputian earthworks—lilliputian in respect of width, although not necessarily so in respect of depth or height. Look at them how you may, and in the light of a strong imagination, and they will appear but a pair of bars temporarily divorced from a common heap. You may compare them, if you have visited the cellars of the great London or Burton breweries, to the narrow lines of way along which casks of beer are rolled into dark distance, and into a highly carbono-acidulous and alcoholic atmosphere therein. You may compare them to the twin sides of an iron ladder, 'barring' the rounds. Yet the 2 ft. railway gauge, or rather the 2 ft. 1 in. gauge, may be seen even in London, and for miles, to the west, out of London. Within the 7 ft. gauge of the Great Western, a third rail has been laid down for the 4 ft. 8½ in. gauge, and, between Didcot and Wolverhampton, the inner rails of the 7 ft. gauge have been removed, leaving the old 'six foot,' as the intermediate space is termed, about 11 ft. wide, between the two 4 ft. 8½ in. gauges; the up and down lines, from their distance apart, appearing to belong rather to competing companies than to the same company, and seeming, indeed, to be in adjoining counties, or, at any rate, in separate 'districts.' But between Paddington and Didcot the inner rails of the 7 ft. gauge still

remain, and between them and the inner rails of the 4 ft. $8\frac{1}{2}$ in. gauge is a clear width of 2 ft. 1 in. If the traveller can imagine a real railway of 1 in. less width, he may form some notion of the Festiniog line, not, however, as an entire railway, but in respect of its gauge alone. And would you, the passenger, consent to be whisked down to Didcot, at from thirty to forty miles an hour, over that remanet from the 7 ft. gauge—that remanet of 2 in. —we mean 2 ft. 1 in.—gauge? Look for a little time down that interminable perspective, and the 2 ft. 1 in. gauge converges to 18 in., to 12 in., to 6 in., to nothing at all. Even the 2 ft. gauge at your very feet seems, as you look again and again at it, to contract to 20 in. or even to 16 in. You cannot quite believe it to be even 2 ft., until you have measured it once more, and then you wonder why it was not laid down to a 1 ft. gauge, which, you almost believe, might have answered just as well. Indeed, you verge upon the late Mr. Holworthy Palmer's theory of no gauge at all—a single rail, from which, in his short railway near Posen, in Prussia, he suspended his carriages, but upon which, laid on the ground, you would suppose steam bicycles might be run, especially after Professor Rankine's more than wonderful recent algebraic analysis of how bicycles run at all. It may be—we cannot prophesy—that the velocipedestrian mania may result at last in working heavy trains over a single rail, and the Festiniog is certainly the nearest practicable approach yet made to this mode of working.

"But it is not alone the narrowness of the gauge. There are curves as sharp as the sweep of Oxford Circus—at any rate of but 116 ft. radius for short lengths, while others are of 150 ft. to 264 ft. radius only. It is true they are parabolic curves, eased off from the straight line, and only gradually attaining and as gradually verging from their minimum radius. But over the extra-narrow gauge, and through these curves, almost sharp enough to be called corners, steam-drawn passenger trains are worked at a nominal regulation speed of 12 miles an hour, but at an actual speed sometimes exceeding 30 miles an hour, while the engineer of the line expresses himself equally ready, if the Board of Trade will sanction it, to run 40 miles an hour! And it is the fact that this line, having a total length of $14\frac{1}{4}$ miles, including branches, has been worked by locomotives for more than six years

without a single accident other than what might have equally happened upon any gauge, *viz.* engines or wagons running off at points which had been set wrong. The successful working of the line is *un fait accompli*—a fact of six years' duration. So narrow and so crooked a line has no business to be worked at all; you seem to think it cannot be—never was—worked, but there is the fact. It *does* work, and, what is more, it pays. The traffic receipts of the little Festiniog line, from 30*l.* to 40*l.* per mile per week, exceed those of the North Staffordshire or of the Cornwall Railway, while they are very considerably above those of the Cambrian system of railways, and are greatly more than those of most of the Irish lines. And the whole cost, including half a mile of tunnelling, and an almost uninterrupted series of cutting in syenite rock, and breastwall embankments, or rather rubble stone viaducts, together with stations, workshops, seven locomotives, and more than one thousand wagons and carriages, has been about 6000*l.* per mile. It is the pecuniary success of the Festiniog line, which pays about 30 per cent. upon its original capital of 36,000*l.*, which makes it doubly interesting. Upwards of 50,000*l.* have been expended upon improvements, and this, taken from revenue, has since been capitalized, making a total capital account of, say, 86,000*l.*, upon which about 12½ per cent. is now paid.

"But it is not alone the gauge, nor the curves, nor the safe and profitable working of the line which make it interesting to the engineer. Nor is it even the grand scenery which it commands in the Maentwrog Vale. Festiniog is 700 ft. above Portmadoc, the elevation being accomplished in less than 12 miles, giving an average gradient of 1 in 92, and a maximum gradient of 1 in 80. The line is cut into and embanked upon the steep right-hand slope of this valley, furrowed as is this slope with the deep hollows of the mountain watercourses, and the cuttings, tunnels, and embankments are equally striking with the permanent way itself. The width between the nearly vertical sides of the cuttings is but about 8 ft., allowing hardly room for driving a cab through them; the two tunnels—one of 60 yards, and the other of 730 yards—are scarcely larger in cross-sectional area than the trains themselves; while the embankments, if we may give them that name—the engineer calls them 'breastwalls'—are almost invariably stone walls 8 ft. wide at the top, with a batter of 1 in 6 on each

side. Some of these breastwalls are 50 ft. or more in height, and are sharply curved. There are no parapets, and the passenger carriages almost overhang their edges, presenting a fine opening for destruction. An engineer from any railway of ordinary gauge, especially a double line, would look upon the works of the Festiniog Railway as but little more than a bridle path, resembling certain of the narrow ways in the Alpine passes, or in the world-famed pathway from Laguayra to Caraccas in Venezuela. Indeed, the national duocorn of Wales, the Cambrian goat himself, would hardly find more than comfortable footing along the Festiniog line. Sheep stray upon the line, and we should ourselves have made Welsh mutton of a small flock of them, last Saturday, had they not considerately jumped in time down a steepish embankment. Mr. Fairlie was present to observe the working of his new engine—the 'Little Wonder,' an engine constructed on his double bogie system.

"It is now as certain as anything predicted upon the principle of mechanics can be, that the double bogie engine of the 'Little Wonder' type will accomplish for the Festiniog line a degree of success beyond anything contemplated even by its enterprising manager, Mr. C. E. Spooner, to whom alone (unless his father, the late Mr. James Spooner, be included) is due the credit of introducing steam-drawn passenger trains on the two-feet gauge."

Reprinted from 'The Engineer,' September 24, 1869.

No. I.

"We have during the last five or six years invariably, if not continually, advocated the extended adoption of what has come to be known as the 'light system' of railway traffic. Our views on this subject have been persistently disputed by writers who, we believe, lacked any practical experience in the working of railways of less gauge than 4 ft. 8½ in.; but, on the other hand, it is worth bearing in mind that not a few of the most eminent engineers of the day have admitted that opinions similar to those we have expressed were perfectly correct; while a still more numerous body, conceding that the narrow gauge—a feature in the light

system—was right in theory, reserved their judgment until some practical results in its favour had been obtained. We do not propose here to reopen the entire question, nor shall we do more than allude to the fact that an essential portion of the light system consists in working 4 ft. 8½ in. gauges with combined steam carriages. For the present we shall confine ourselves to the consideration of the merits of narrow gauge lines for local and branch traffic, and in doing so we believe we shall be able to place before our readers certain facts which may tend to modify the opinions of even our most persistent opponents.

"Before proceeding farther, it will be as well to put on record here, in the most compact form possible, the arguments urged for and against narrow gauge railways. In favour of narrow gauge railways, we state that their cost of construction is very small as compared with that of ordinary lines; that the expenses for maintenance are very moderate; that the proportion which the dead weight moved bears to the whole load rapidly diminishes with the width of gauge; that a high rate of speed may be maintained with safety on narrow gauge lines; that very sharp curves may be traversed with safety when the rails are close together, which could not be traversed at speed at all if the rails were more widely spaced; that narrow gauge can be used with safety and success for the carriage of passengers; and, lastly, that narrow gauge lines can be constructed and made to pay in districts and under circumstances which preclude all hope of a dividend from railways of ordinary dimensions. Our opponents urge, on the other side, that it costs as much per mile, within a mere trifle, to make a railway of 2 ft. or 2 ft. 6 in. gauge as to make one of 4 ft. 8 in.; that speeds greater than ten or twelve miles an hour are inadmissible on very narrow roads; that it is just as dangerous to traverse very sharp curves on the narrow as on the broad gauge; that no saving whatever can be effected in the cost of conveying a ton of goods or passengers a mile; that narrow gauge roads are behind the age; and, finally, that wherever there is room for a railway at all it should be made full size. This is, we think, a fair exposition of the arguments for and against narrow gauges. It is indisputable that of late a very strong feeling in favour of cheap railways has sprung into existence in the minds of men of high position and great influence. The accuracy of the principles we have indicated,

and the recognition of which in practice we have advocated, is beginning to be recognized. Popular feeling tends to turn strongly to our side, and under the circumstances we make no apology for placing before our readers, at considerable length, particulars of the construction and working of the narrowest railway, carrying passengers, in the world, convinced as we are that such facts as we shall adduce possess an enormous importance for those who would develop the resources of the country by providing better and more complete means of intercommunication. This narrowest railway is that which unites Portmadoc, in North Wales, with Festiniog and its slate quarries. Within the last week we have gone over this line four times, and thanks to the courtesy of Mr. C. E. Spooner, C.E., the engineer of the line, we were supplied with every possible facility for making ourselves acquainted with the construction of the line, and of the engines, &c., working it. As to the mode of working, and the results obtained in working, we were placed in a position to obtain the fullest information which could be obtained. Most of our readers have, no doubt, heard of the Festiniog Railway, and believe, or more properly think, up to this moment that it is nothing more than a horse tramroad on which a couple of rough little colliery locomotives have been put to work. We beg them at once to disabuse themselves of this notion, which has no foundation in fact. The Festiniog Railway is a miniature line, the working arrangements of which are modelled on those of other lines in the kingdom. The signals, the stations, the engines, the carriages, and the rolling stock generally are, equal in finish, and perhaps superior in efficiency, to that of any railway in the kingdom; while the permanent way, now being rapidly relaid by Mr. Spooner, is in finish, quality, and system of construction, equal to that of any line in the world in its way.

"On the 11th of April, 1865, Captain Tyler (Government Inspector) read a paper before the Institution of Civil Engineers, entitled 'On the Festiniog Railway for Passengers; or a 2 ft. gauge, with sharp curves, worked by locomotive engines.' To this paper we are indebted for some particulars of the first life of the line. Captain Tyler described what he saw in 1865, but the energy of Mr. Spooner and his directors has wrought many great changes in the last four years, and even Captain Tyler would find a second

visit to the Festiniog Railway fully repay him for the trouble of going to it—a tedious journey enough it must be admitted.

"The Festiniog—or, to spell it Welsh fashion, the Ffestiniog—Railway was constructed about the year 1832 as a horse tramroad. It commences at the quay of Portmadoc, crosses an embankment made by a gentleman, who ruined himself by the undertaking, to reclaim a large waste of slop land from the sea, and runs for thirteen miles through a country the wild magnificence of the scenery in which can scarcely be equalled even in Wales, to the hamlet of Dinas—pronounced Deenàs—in the district of Festiniog. Here it branches out into four or five lines, which ascend by gradients varying from one in five to one in three-quarters, to the slate quarries in the Festiniog mountains. It is almost needless to say that these branches are worked neither by engines nor horses; they are self-acting inclines, on which the full slate wagons running down haul up the empties by means of a wire rope and drum. Of these inclines, and the quarry system of Festiniog in general, we shall have a good deal to say at another time. The trains are made up at the foot of these inclines, and collected at Dinas, to be conducted by locomotives to Portmadoc. The line is on an ascending gradient the whole way—there is not so much as one yard of level. The average rise is 1 in 92 for twelve and a-half miles. The steepest gradient over which passengers are carried is 1 in 79·82; but some portions of the collecting lines at Dinas are worked by locomotives over a gradient of 1 in 60. The Traeth-mawr embankment, before referred to, about 900 yards long, is nearly level, rising slightly towards Dinas. It is not practicable, by any possible kind of writing, to give an accurate idea of the nature of the country traversed. The line follows the Vale of Festiniog, being scarped out of the mountain side. Ravines have been bridged over or crossed by what are known as breastwall works. In not a few places it is possible, standing on the engine, to kick a shoe down a sheer depth of 100 ft.; in others, ravines are crossed by embankments of dry stone not more than 10 ft. wide at the top, and at least 60 ft. high. If we were asked to draw a plan of the line from memory, we should simply repeat the letter **S** many times. A moderately long train may be on three curves at once. The sharpest curve, nearly a half circle, is 1¾ chain radius, and the others vary from 2¼,

$2\frac{1}{2}$, $3\frac{1}{4}$, to 5 chains, &c. The line has recently been modified, as far as practicable, by Mr. Spooner, all the curves having been rendered parabolic, which system, although it renders them sharper in the middle, makes the entrance excessively easy. The fact that although the line has been worked by locomotives for six years, no train or engine has ever been off except twice, when the points were left open by the negligence of a signalman, and when no injury whatever was done to either rolling stock or passengers, is admirable testimony to the success with which the parabolic system has been adopted. There is one tunnel 60 yards long, and another 730 yards long; the first cut through shale, and the latter through syenite rock. These tunnels are so small that they barely permit the engines to pass through. A tall man standing on the foot-plate must crouch that his head may clear the roof, and woe to him if he allows a hand or a foot to hang out beyond the width of the engine, which clears the tunnel by about 4 in. only at each side. The permanent way is partly old, partly new. The renewal is rapidly being carried out by Mr. Spooner. The old portion consists of single-headed rails, without any bottom flange—T this section—weighing 30 lbs. to the yard. They are in lengths of 18 ft. to 21 ft., laid in 10-lb. chairs spiked to cross sleepers. The new rails weigh about $48\frac{1}{2}$ lbs. per yard, are 24 ft. long, and are fished at the joints by a very ingenious fish-plate, which we shall illustrate in another impression. The joint chairs are carried on a square sleeper frame. The whole arrangement is very clever, reflects much credit on Mr. Spooner, and leaves the rail as strong at the joint as anywhere else.

"The rolling stock has been considerably modified since Captain Tyler wrote his paper. In the third-class carriages the passengers are still carried back to back, but the first and second class resemble ordinary carriages in every particular. One first-class carriage which we measured may be taken as typical of the rest. It was fitted with four seats, each seat holding three passengers. The height in the centre is 5 ft. The length of the body is 9 ft. 6 in. The length of each compartment is 4 ft. 6 in., and the height from the floor to the seats is 1 ft. 2 in., to which the cushion must be added. The breadth over all is 6 ft. 3 in. The wheels are 1 ft. 6 in. in diameter, fitted with volute springs. The axle-boxes are got at through doors in the seats, and can be easily oiled and examined.

The weight of the carriage complete is 30 cwt. only; the buffers are central. The slate wagons are of two kinds, one 'small,' weighing 13 cwt., and holding about two tons of slates; the other 'large,' weighing 17 cwt., and holding three tons of slates. They have open-work angle-iron sides and boarded bottoms. The following are the dimensions of one which we measured:—Length, 6 ft.; width, 2 ft. 11 in.; depth, 1 ft. 6 in.; wheels, 1 ft. 6 in. diameter, fast on the axles; wheel base 3 ft. 2 in. long. Wagons are also used for the conveyance of goods, ballast, casks, &c. The following are the dimensions of one from actual measurement:—Length, 7 ft. 6 in.; height, 2 ft. 11 in.; width, 2 ft. 11 in., all inside body; height from rail, 5 ft.; wheels (four), 1 ft. 6 in. diameter; wheel base, 3 ft. 8 in. There are also powder wagons, arched top coffers of $\frac{1}{4}$ in. iron plate, 6 ft. long, 3 ft. wide, and 3 ft. 6 in. high. Brake vans, timber trucks, and covered goods wagons, all resembling in miniature those found on ordinary lines; and besides these, a set of cars for the quarrymen, and a machine known on the line as 'the boat,' which looks like a slice off the bows of a wherry, mounted on four high wheels.

"At the time Captain Tyler wrote there were only four engines on the line, there are now seven. The first four were built by Mr. George England, of the Hatcham Ironworks, New Cross. They weigh full $7\frac{1}{2}$ tons. They have four coupled wheels, 2 ft. only in diameter. The cylinders are outside the frame. Subsequently two other engines were built by Mr. England, weighing 10 tons full, with 2 ft. wheels and 8 in. cylinders, 12 in. stroke. The working pressure is 160 lbs., but 200 lbs. have been carried. Within the last few weeks a seventh engine has been added, 'The Little Wonder.' It was also built at Hatcham. It is a double bogie engine, designed by Mr. Fairlie. The boiler is of steel, with a mid-feather across the fire-box. The following are the particulars of the 'Little Wonder':—Diameter of cylinders, $8\frac{1}{4}$ in.; length of stroke, 13 in.; diameter of wheels, 2 ft. 4 in.; diameter of boiler, 2 ft. 6 in.; length of barrels, 7 ft. 6 in.; length of fire-box, 6 ft.; width of fire-box, 3 ft.; height of fire-box, 4 ft. 6 in.; length of copper fire-box, 5 ft.; width of copper fire-box, 2 ft. 6 in.; height of copper fire-box, 3 ft. 6 in.; grate area, 11 square feet; heating surface, 60 square feet; heating surface of tubes, 670 square feet; total heating surface, 730 square feet;

number of tubes, 218; diameter outside, $1\frac{1}{4}$ in.; length, 7 ft. 10 in.; capacity of tanks, 90 gallons; coal bunkers, 15 cwt. The working pressure is 160 lbs. The length of the engine over all is 27 ft., and its weight, in working order, is 20 tons, carried on eight wheels; so it will be seen that Mr. Spooner is getting on. After carefully testing this engine, we came to the conclusion that whatever may be said by its opponents, of the Fairlie system for main line traffic, it is exactly the thing for narrow gauge work. In order to ascertain exactly what its performance is, we went over the line twice on the 'Little Wonder,' and twice on one of the old 10-ton engines, the 'Little Giant,' with results which we shall now proceed to give.

"At a little after 1 P.M. on Saturday last, the 'Little Wonder' left Portmadoc for Festiniog in such a storm of wind and rain as we do not care to encounter again. She had behind her a train consisting of

	Weight. Tons.	Cwts.	Length. Yards.
111 Slate Wagons	74	0	287
6 Carriages	9	0	22
60 Passengers	4	10	—
12 Goods Wagons	26	6	30
	113	16	339
Add the Engine	20	0	9
	133	16	348

"Thus we have a total load of 133 tons 16 cwt., and a total length of train, 348 yards. This train the engine took with much ease up to Hafodllyn, a distance of $7\frac{1}{4}$ miles, over the worst part of the road. Not far from Hafodllyn the long tunnel already referred to commences, and after consultation it was determined to take off some of the slate wagons, as it was feared the engine would get stalled in the tunnel by slipping; and as no one can get off the engine or get out of a carriage, the tunnel is a peculiarly nasty place in which to stick, even for a minute. All the wagons might have been left on, however, as the engine rushed through with the slightly-diminished load in one minute and five seconds, or at the rate of 23 miles per hour nearly. The return journey commenced about three-quarters of an hour after the experimental train arrived at Dinas. Only a few slate

wagons were on in addition to the passenger train; over the new portion of the road a speed of over 25 miles an hour was attained with ease, and on one occasion a velocity of about 35 miles an hour was reached, the bogie engine swinging round the curves with graceful ease and a total absence of strain or jerk. We did not take the time spent in running to Hafodllyn, but from Hafodllyn to the beginning of the embankment, a distance of a little over $6\frac{1}{4}$ miles, the time was as follows:—Started from Hafodllyn at 4.6 P.M., stopped at Penrhyn at 4.20, started again at 4.24. Stopped to take tickets at end of embankment at 4.30. Total running time 19 minutes, equivalent to 19·74 miles per hour. It is worth while to consider here the nature of the work done by the engine when running at 20 miles an hour. During each minute the train passed over a distance of 1760 ft., and as the wheels were 2 ft. 4 in. in diameter, they made 240 revolutions per minute, a velocity increased during many portions of the run to as much as 360 revolutions per minute; but even at this tremendous speed—corresponding to a velocity of about 90 miles an hour for a 7 ft. wheel—the engine ran with an almost total absence of oscillation, nor did the bearings heat in the slightest degree. A speed of 90 miles per hour has never yet been attained on any railway, and up to the present moment it follows that the narrow gauge has beaten the ordinary gauge in its relative power of transporting passengers at high velocities. Nor is it to be assumed that 35 miles an hour is a limit which cannot be exceeded. It is to be borne in mind that the Festiniog engines are really goods engines in relation to the road on which they run. The 'Little Giant,' with 2 ft. wheels, works under just the same relative conditions as a 4 ft. $8\frac{1}{2}$ in. engine, with 4 ft. $8\frac{1}{2}$ in. wheels. No one expects an express speed from such engines; but there is no good reason why the Festiniog line should not be worked with 3 ft. wheels, that is to say, a gauge and a-half high—a proportion adopted in many of the best engines of the day, which have driving wheels 7 ft. 1 in. in diameter."

No. II.

"We have stated that in order the better to master the details of the working of the Festiniog and Portmadoc Railway we traversed it from end to end four times, twice on Mr. Fairlie's

engine, the 'Little Wonder,' and twice on one of the old pattern engines, the 'Little Giant.' The results of the two first trips we gave in our last impression; we have now to place before our readers those of the other two.

"We left Portmadoc shortly after 8 A.M. on the morning of Monday, the 20th instant, and reached Festiniog, or more properly Dinas, in about an hour and a-half, including of course several stoppages on the way. The train consisted of forty-one slate trucks, empty, five passenger carriages and a brake van, one rail-bending machine,* and the 'boat' before referred to. The weight of the whole, including thirty passengers, was 51 tons, or with the engine 61 tons. Steam was maintained with much ease at 160 lbs. in the boiler. The manner in which the little engine with its 2 ft. wheels crept, caterpillar-like, up the steep road was remarkable enough to unaccustomed eyes. The first two or three miles proved pretty clearly, however, how great a step in advance, how much real progress, Mr. Spooner had made when he put the double bogie on his line. The 'Little Giant' shoulders her work in a very curious fashion. She gets over the road not steadily, as she should do, but by a series of efforts rapidly repeated. As each cylinder alternately drives the engine by the pressure on the forward cylinder lid, that side advances before the other by a distance perceptible enough to any one on the foot-plate at slow speeds, the head of the engine sidling across the rails, while at high speeds there is all the lateral oscillation that at one time earned for certain engines the title of 'boxers.' From the great length of overhang at the fire-box end, again, the engine jumps most unpleasantly, although the little tender, carrying coal only, is coupled up as tightly as possible to the foot-plate. Over the old portions of the road a speed of eight or nine miles an hour is the greatest at which it is possible to run without incurring the risk of breaking the springs, or loosening the driver's teeth. In the double engine, as a matter of course, nothing of the kind is felt, owing to the length of wheel base; nor is there any shouldering or lateral oscillation due to the action of the steam on the cylinder covers, because, in the first place, the mere length of the machine tends to act as a corrective, and, in the second, because the two engines never beat together, except by accident for a few seconds. As will be seen,

* This is a very ingenious machine of Mr. Spooner's invention.

the load taken up by the 'Little Giant' was less than one-half that taken by the double bogie engine. It must not be understood that 51 tons is the maximum load for the lighter engine, as many as 80 tons having been taken on a pinch; but it was certainly quite as many as she could keep steam for comfortably at ten or twelve miles an hour. The double bogie engine is probably not more heavily loaded with 130 tons than the 'Little Giant' is with 60 tons; and when the former has come to her bearings and worn herself smooth she will probably be quite up to loads of 140 tons, including her own weight. The question is here purely one of keeping steam, and this again depends not a little on the relative efficiency with which the steam is worked in the cylinder. The 'Little Wonder' has a considerable advantage in the greater height of wheel, which reduces the waste per mile due to clearance and port space. It did not fail to strike us that the ordinary engines are underpowered, as far as economy is concerned, for loads of 50 tons. It is impossible to expand steam in their cylinders to any appreciable extent; the noise of the exhaust, indeed, resembles revolver firing more than anything else. With a more powerful engine and more cylinder room, coal could not only be burned more economically, but the steam used to more advantage. The strain on the engine would be reduced, the back-pressure diminished, the fire less cut up, and, in a word, coal bills generally kept down. Of course, if the loads to be hauled had remained very moderate, the single engines would have answered every purpose. They were designed to haul about 35 tons at 10 miles an hour, but loads have not remained moderate. On the contrary, as we shall show presently, they have augmented, and are augmenting daily. It is very easy to build engines which will suit a narrow gauge line, so long as the loads are kept to narrow gauge proportions; but when we find loads approximating to those carried on the 4 ft. 8½ in. gauge, thrown upon the 2 ft. gauge, the problem does not admit of such easy solution. Now it is pretty good work for an ordinary locomotive to take fourteen carriages weighing, filled, about 120 tons, up a gradient 13 miles long, rising at the rate of 1 in 98, and abounding in curves of from 4 to 5 chains radius, at 30 miles an hour. Yet the 'Little Wonder' actually did this duty, the speed being reduced somewhat in the relative proportions of the gauges, this reduction

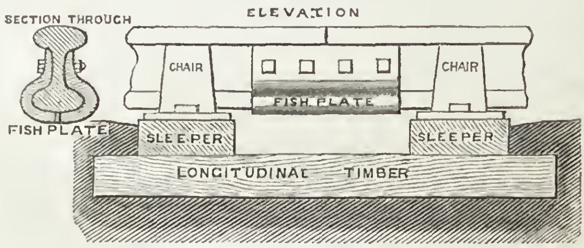
of speed being, of course, a natural consequence of the reduced weight of the engine. A locomotive weighing 20 tons with coal and water, and having less than 700 ft. of heating surface, cannot be expected to do as much work as an engine with 1100 ft. of surface, and weighing over 30 tons without coal and water. With the 2 ft. gauge especially, and on lines curved anything like the Festiniog Railway, the only solution of the problem lies in the adoption of four cylinders, for the very same reasons as those which led to the adoption of four-cylinder engines on the Chemin de Fer du Nord, and some other lines conveying goods and minerals in trains too heavy, in one sense, for the gauge. In the selection of the proper class of locomotive for any line will lie one great element of economical working; but the selection of the right kind of rolling stock for lines like that under consideration is a matter of the most vital importance. We shall probably astonish many of our readers when we tell them that the consumption of fuel up to the present time has amounted to a little over 50 lbs. per train mile, or about double that of an ordinary well-proportioned passenger engine. This fact may appear at first sight to tell heavily against the whole system; but a little examination will show that the 50 lbs. a mile is subject to many and important deductions. In the first place, it includes the entire consumption of fuel standing as well as running. Each engine is under steam about fourteen hours a day. The actual running time out of this is about three hours only; during the remainder the engines are either shunting in the yard, standing under steam, or making the return journey down the incline, during which the fire has of course to be kept up, and, generally speaking, the blower on. The true working consumption it is obviously very difficult to get at. As nearly as we could ascertain, 3 cwt. of coal will take the 'Little Giant' up to Dinas with 50 tons behind her, and down again to Portmadoc, which is equivalent to about 22 lbs. per mile going up. This is too much, however, and admits beyond doubt of considerable reduction, first by improving the permanent way, and secondly by augmenting cylinder space by using four instead of two cylinders, and so giving the driver a chance to work his engine in nearly full gear. The coal, too, is nothing like so good as that used on first-class lines—a matter which deserves consideration when we come to compare the relative efficiency in fuel of several different engines.

Considerable advantage, too, would beyond question result from an augmentation in the diameter of the driving wheels. They should under no circumstances be less than 2 ft. 6 in. high; 2 ft. 9 in. would perhaps be better, the tractive force being kept up by proportionally increasing the length of stroke. But above and beyond all this it must not be for a moment forgotten that the Festiniog line cannot be taken as a fair sample of what an extended system of lines on the 2 ft. or 2 ft. 6 in. gauge would be. It passes, as we have already explained, through an impossible country; and the excessive, and beyond measure vexations, rules as to head way and side way to which Mr. Spooner has had to conform no doubt place the system at a great disadvantage. As an example, we may adduce the fact that low as the engine wheels are, the engine funnels are excessively short, and even now hardly clear the roofs of the tunnels or the soffits of the accommodation bridges across the line. This reduction in chimney length tells of course on the draught, renders an otherwise excessive use of the blower indispensable, and is accompanied of necessity by a reduction in the diameter of the blast-pipe, which cannot fail to increase considerably the consumption of fuel.

"Of our fourth trip, from Dinas to Portmadoc, little need be said, as the engine had no work to do, descending with the trains almost altogether by gravitation. The same disagreeable jumping motion was of course apparent; but although running tender first, the curves were taken with remarkable ease and steadiness on the new track, and a speed of about 14 miles an hour there maintained without undue oscillation.

"In our last impression we referred to the rail joint used by

Fig. 6.



Mr. Spooner. The accompanying sketch will show its precise character at a glance. The fish-plate, it will be seen, grips the

lower flange, and the practical result is that not only is the line stiffened, but the nuts lose their tendency to turn back. The sleepers are arranged in the form of a square framework. We may add that we have never had the fortune to run over a better jointed road than Mr. Spooner's.

"As the working expenses of such a line as that under consideration cannot fail to present questions of interest, we are pleased to be able, thanks to Mr. Spooner, to place the following facts before our readers. They show clearly how enormously the traffic has increased of late, and of what so narrow a line is capable. It may be as well to premise that at present but six trains each way are run in the day, but the number can be doubled without inconvenience. The accounts are at present only available for our purpose to June, 1868, the report for 1869 not yet being made public. For the year ending June, 1868, the working expenses were as follows:—Maintenance of way, 1069*l.* 15*s.* 8*d.*; masonry, 104*l.* 17*s.* 8*d.*; locomotive department, 699*l.* 16*s.* 7*d.*; tonnages, 1222*l.* 11*s.* 9*d.*; station-masters and staff, 2353*l.* 3*s.* 6*d.*; salaries, 264*l.* 4*s.* 10*d.*; parish rates, 779*l.* 9*s.* 6*d.*; passenger duty and income-tax, 382*l.* 0*s.* 9*d.*; general charges, 266*l.* 4*s.* 1*d.*; timber, coal, and iron, 1980*l.* 14*s.*; rolling stock, 1072*l.*; total, 9694*l.* 18*s.* 6*d.* The total receipts amounted to 22,852*l.* 13*s.* 5*d.* The working expenses, therefore, came to about 42 per cent. of the income; and it will be noticed that in the working expenses are included income and other taxes, and a toll to Mr. Bankes, and to the Tremadoc estate for crossing the Traethmawr embankment. The average proportion borne by working expenses to receipts on English railways, in general is 48 per cent. It will therefore be seen that Mr. Spooner works, perhaps one of the most difficult roads in the world, at a price so much lower than the regular rate that, could all English railways be worked at the same cost, high dividends would be the rule and low dividends strictly exceptional; and there can be no doubt whatever that when Mr. Spooner has relaid his roads, got better engines, and ceased to charge to working expenses what most directors would charge to capital, the working expenses of the Festiniog Railway will be still further reduced. As regards the development which the traffic has undergone, we cannot do better than use Mr. Spooner's own words:—

"'The accounts,' says Mr. Spooner, in his report for 1867–68,

'that I have the pleasure to submit the proprietary for the past year, ending 30th June, show a large increase of traffic over that of the preceding year. The quantity of slates carried over the line amounts to 112,051 tons 19 cwt., and carriage of merchandise 14,693 tons 11 cwt. 2 qrs., making together 126,745 tons 10 cwt. 2 qrs. The total receipts for the twelve months amounted to 22,852*l.* 13*s.* 5*d.*, and the money value of increased stock to 5655*l.* 14*s.* 3*d.* The expenditure was 17,871*l.* 6*s.* 5*d.* The increase on carriage of slates, as compared with the past year, is 18,278 tons 19 cwt., productive of 2401*l.* 8*s.* 7*d.*; merchandise traffic, 903 tons 11 cwt. 2 qrs., productive of 242*l.* 15*s.* 6*d.*; and passenger traffic, 714*l.* 0*s.* 4*d.* The increase of train mileage was 2449, or as 46,732 miles run for the past year to 44,283 for the year ending 30th of June, 1867. The two locomotive engines ordered last year, together with railway bars and fish-plates, have been paid for, as appears by the accounts; such new rails and plates are sufficient for 2½ miles of line, three-quarters of a mile of which have been laid to permanent way. In consequence of the additional numbers of inclined planes at the various slate quarries beyond the upper termini of your line, and the increase in the production annually of slate, there has arisen the necessity of a larger stock of slate wagons, and a considerable addition to the annual expense of repairs at the company's works. As there is every probability of a progressive increase in the traffic, it is important that an ample supply of slate wagons and other rolling stock be maintained to meet it.'

"We now come to the most important fact of all. At the annual general meeting held in August, 1868, a dividend of no less than 6 per cent. for the half-year was declared. Hear that, ye holders of ordinary railway stock! 12 per cent. per annum from railway property! Why is this result obtained? Simply because the line which gave it was cheaply made and is cheaply worked. It is adapted to its purpose; it is not too big for its traffic. Instead of 40-ton engines and tenders, we have engines and tenders of a fourth of the weight. Instead of first-class carriages weighing 7½ tons, and accommodating thirty-two passengers, representing 4¾ cwt. of dead weight per passenger, we have carriages weighing 30 cwt., holding twelve passengers, or 2½ cwt. per man; and advantages similar in character hold good of all the passenger vehicles. Then

we turn to the goods stock, what do we find? Slate trucks weighing 17 cwt. holding three tons, and coal and other trucks in which the proportion of dead to paying load is about the same. On the 4 ft. 8½ in. gauge eight tons of coal, &c., are commonly carried in trucks weighing 4 tons 6 cwt., 4 tons 11 cwt., &c. On few ordinary lines does the paying load exceed the dead weight by more than three-fourths. We shall not prolong our account of the Festiniog line by showing why it is that the dead weight must increase in a very rapid proportion with each increase in gauge. One fact is worth a bushel of theory, it is said, and the Festiniog Railway affords the best possible proof that a reduction in gauge to a little less than one-half that which is normal to Great Britain, permits a reduction in the weight of rolling stock as compared with a load of the utmost possible importance to the proprietary.

"We do not wish to be misunderstood even for a moment. We do not pretend that all the lines in England would have been better had they been constructed to a 2 ft. gauge. Far from doing so, we state explicitly that we consider the 2 ft. gauge too narrow for any line. In order properly to develop the resources of this great country two systems of railway are apparently indispensable. First-class or main roads of comparatively wide gauge, and feeders of narrow gauge. Were the railways of this country to be laid out again, we should advise the construction of such roads as the London and North-Western, Great Northern, &c., to a 5 ft. gauge. There is not much to complain of about the 4 ft. 8½ in. gauge, but there is a little. It is too narrow to permit locomotives with large inside cylinders being placed upon it, unless the valves are turned over the tops of the cylinders, or set at an objectionable angle, and it rather limits the diameter of the boiler. Now the extra 3½ in. gained by adopting 5 ft. instead of the normal gauge, would just have disposed of this difficulty, and enabled locomotive superintendents to arrange all their machinery without trouble. For the feeders we should adopt a gauge of 2 ft. 6 in., precisely half that of the main lines; and on these feeders the speed might be half that observed on the main roads—say 16 to 22 miles per hour. The great error hitherto committed in constructing feeders has lain in making them out of all proportion too big and heavy for their traffic; and this mistake has no doubt arisen from the belief that great evils would be entailed by asking

passengers to change carriages. But as a matter of fact, this difficulty has not been obviated by the adoption of the 4 ft. $8\frac{1}{2}$ in. road. The direct effect of the operation of this mistaken belief in the necessity for 'oneness' of gauge has brought about numerous evils. The resources of half the country are not developed. Capital which might be beneficially invested lies idle, or is spent in absurd schemes. Who will take in hand the introduction of a second series of railways to a 2 ft. 6 in. gauge to feed main lines? Who will obtain from Parliament the repeal of the most stupid bill ever passed, rendering the construction of lines less than 4 ft. $8\frac{1}{2}$ in. for passenger traffic illegal? Neither the day nor the man yet has come; but our readers may rest assured that with the advent of both, a new time of prosperity will dawn on the existing railway world, and the blessings of ample facilities for intercommunication will be conferred on towns and districts now, in a sense, beyond the pale of civilization.

"We do not write this simply because the Festiniog Railway is a success—far from it. The Festiniog Railway and its working only prove in a very practical way certain great truths which have not yet received the recognition which they deserve. Even though the line were, commercially speaking, a failure, the failure would not alter mechanical laws. Engineers who have studied the subject in all its bearings have long since seen that by properly proportioning the rolling stock to the road it is as easy to work a 2 ft. gauge with safety as one of double or treble the width. But there are certain men and certain minds which cannot understand mechanical truths unless they are presented to them in a very matter-of-fact form. The Festiniog Railway supplies the only manner of proof which these gentlemen can understand. There is, besides, a large section of the public, which, knowing nothing of the reasons which lead up to the adoption of different systems of construction, judge of the merits of these simply by the results. For both classes we have especially written this and the preceding article on the same subject. If we have shaken a prejudice, or convinced a waverer, or induced one man of talent and experience to believe that there is more in narrow gauge railways than was dreamt of in his philosophy, then have we not written in vain.

"In conclusion, we have to state that we have received a letter

from Mr. Spooner, correcting one or two slight inaccuracies in our last article. The long tunnel clears the sides of the locomotives by a distance of from ten to fifteen inches. In the upper parts of the road where wall and rock approach to within five inches of the engine, changes and modifications will soon be made giving more room. The Festiniog Company possess several coal trucks larger than those the dimensions of which we have already given. These last are 9 ft. 3 in. long, 4 ft. wide, and 3 ft. deep. The wheel base is 6 ft., and the wheels are 18 in. in diameter. These trucks hold 3½ tons of coal or 4½ tons of sand or lime."

Paper read by C. E. Spooner before the Railway Commissioners appointed to investigate the Festiniog Narrow Gauge Railway and the Fairlie System of Locomotives.

The following paper having been handed to His Excellency the Count Bobrinskoy, and he considering it would be desirable that the information it contained should be made known to the large number of gentlemen who, together with himself and party, had travelled so far to see the Festiniog Railway, proposed to Mr. Spooner (the proposal being warmly seconded by His Grace the Duke of Sutherland), that he should read his paper to a meeting of the entire party, with a view to its being fully discussed and examined.

Mr. Spooner having assented, the meeting took place at the Tan-y-Bwlch Hotel, on the evening of the 12th February, 1870,

HIS GRACE THE DUKE OF SUTHERLAND in the Chair.

Mr. Spooner, on introducing his paper, gave the following short address :—

My Lord Duke, Your Excellency, and Gentlemen:

It being intimated to me that a short history of the Festiniog Railway, with the particulars of its construction and working, would, at this time, be interesting to all who have honoured the

directors of this Company and myself with this visit to inspect our little line in its daily working, I have prepared the following statement of facts connected with it, and have added my ideas on the question of gauges and their comparative merits.

I shall be most happy to answer any questions arising out of the reading of the paper, and to give any additional information in my power.

I am a strong advocate for narrow gauge railways, having, from a long experience, fully proved the advantages resulting therefrom —advantages which are, since the introduction of the Fairlie engine, enormously increased.

The paper having been read and discussed, it was proposed by Captain H. W. Tyler, who kindly acted as secretary on the occasion, and seconded by Mr. Juland Danvers, that, with the consent of the Count Bobrinskoy, Mr. Spooner's paper be printed and circulated amongst the gentlemen present.

The Count Bobrinskoy consenting, it was resolved the paper should be printed accordingly.

His Grace the Duke of Sutherland, on behalf of himself, the Count Bobrinskoy, and the gentlemen present, in a few very appropriate words, thanked Mr. Spooner for his very able and lucid paper, which he considered would be of great value in determining the most suitable gauge for railways of the future both at home and abroad, and especially in sparsely-populated countries with limited traffics, where the usual expensive style of constructing railways was most inappropriate, and where the question to be decided was, railways or no railways?

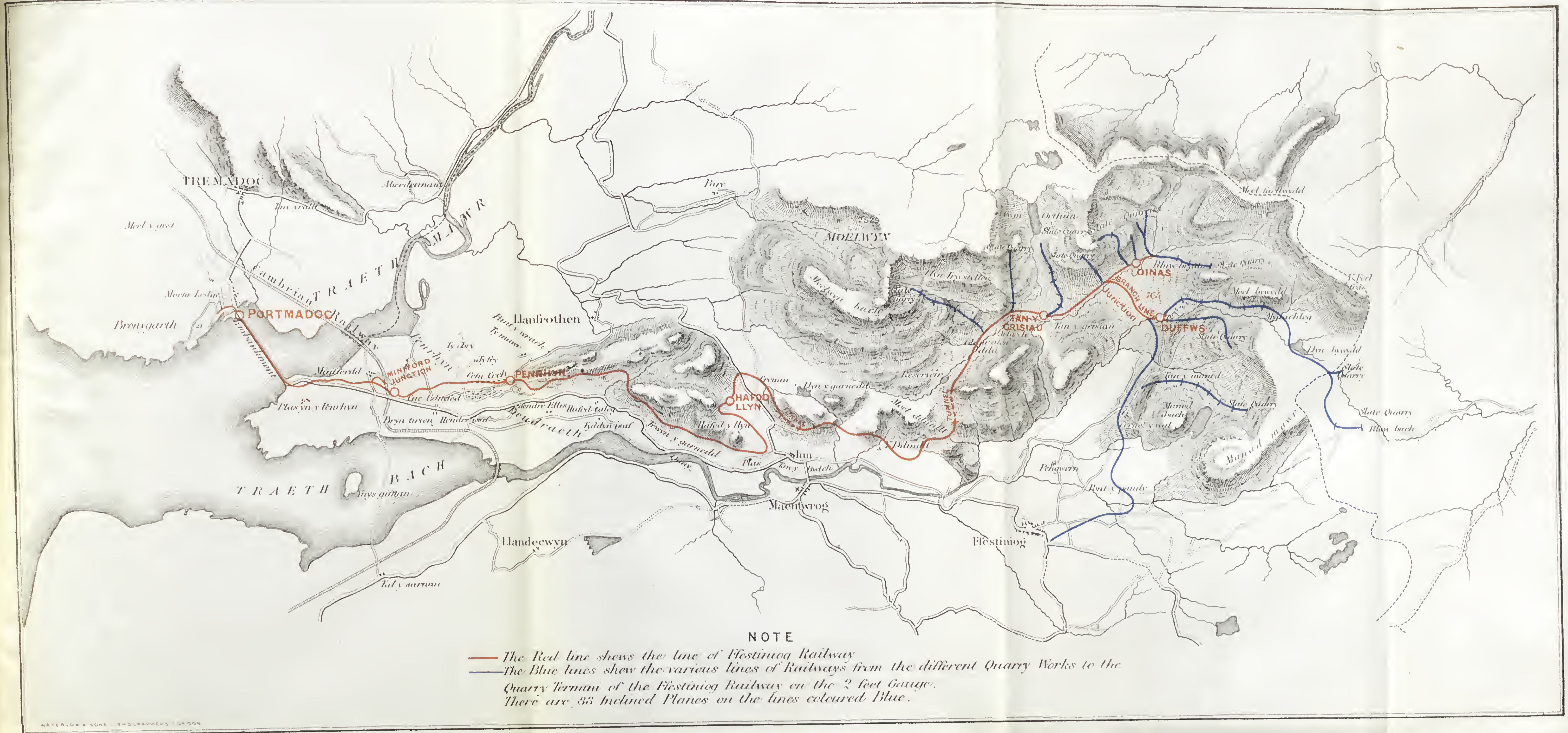
Description of Line.

This railway is a single line of way, commencing at certain slate quarries in the district of Festiniog, terminating at the shipping port of Portmadoc in North Wales.

The length of main line is 13¼ miles, with a branch of one mile.

The difference in elevation from the sea level to upper terminus is 700 ft., being continuous ascending gradients. The maximum gradient is 1 in 68·69, and minimum 1 in 186 (except on the Traethmawr embankment, where the line is practically

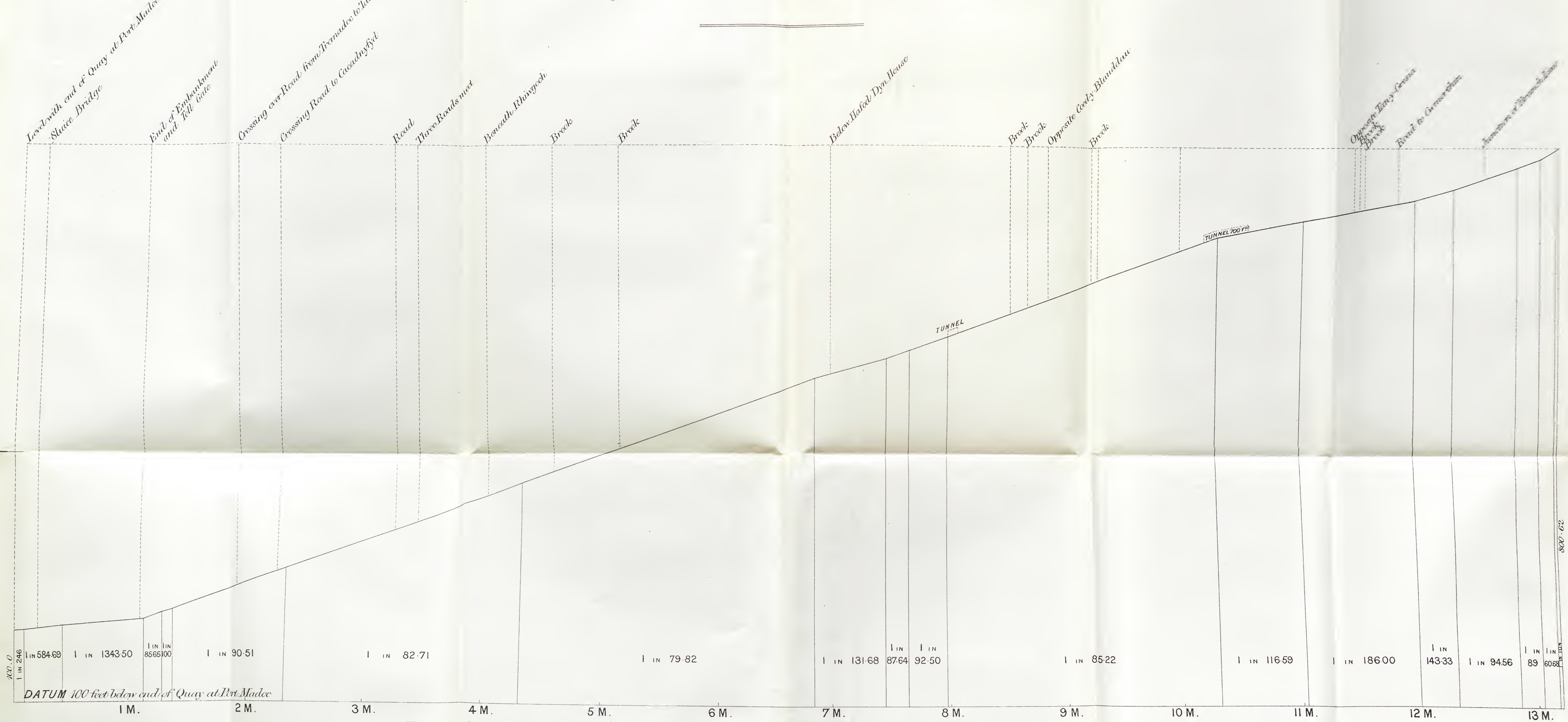
PLAN OF FESTINIOG RAILWAY.



FESTINIOG RAILWAY.

DIAGRAM OF GRADIENTS BETWEEN PORTMADOC & FESTINIOG.

Horizontal Scale, 4.7 Chains = 1 Inch. Vertical Scale 100 F.t = 1 Inch.



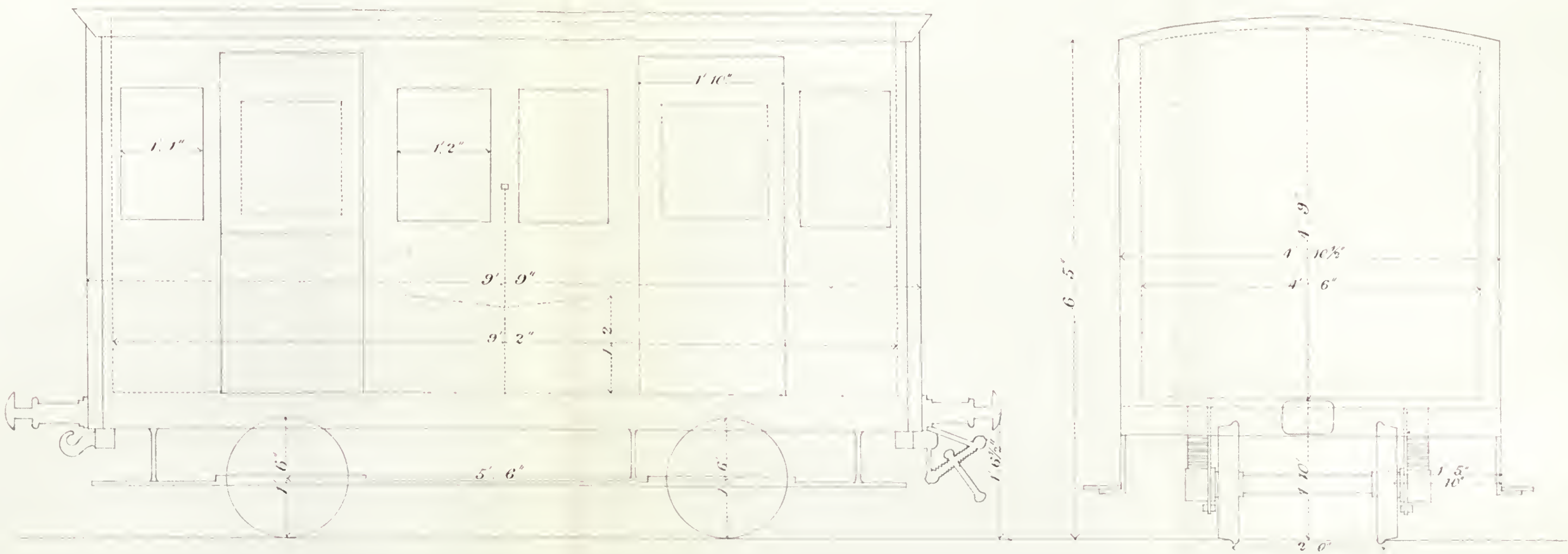
The Curves of this line are so numerous & so small in radii from 1¾ Chains & upwards that they cannot be shown on Plan with the above horizontal Scale.

Skeleton Plan

PASSENGER CARRIAGE Nº 10.

Now in use on the

FESTINIOG RAILWAY.



Scale ½ inch to the Foot.

Note. _ *Has the usual Lamp in roof.*

WATERLOW & SONS, LITHOGRAPHERS, LONDON.

level for one mile). The average gradient is 1 in 92 for $12\frac{1}{4}$ miles.

The line runs through a rude rocky country. The greatest filling is 60 ft., and cutting 27 ft.

The width of line between fences in parts is 8 ft., and on embankment 10 at formation level.

There are two tunnels, one of 730 yards through syenite, and one of 60 yards through slate formation, neither of which is lined.

The gauge of line is termed 2 ft. gauge, but in reality is somewhat less (1 ft. $11\frac{1}{2}$ in.).

The maximum curves are $1\frac{3}{4}$ chain radius in length from 80 to 200 ft. There are others of 3, 4, 5 and 6 chains, the ruling curves being 7 and 8 chains. Nearly the whole of the line is a succession of curves following the contour of the hills.

Many of the fillings are built through and through in dry stone masonry, and others with retaining walls, having the intermediate space filled with soil.

The fences are chiefly dry stone masonry coped in mortar.

The culverts are in dry masonry, faced in mortar.

The bridges are of stone masonry, with the exception of one, over a turnpike road, which is an iron girder bridge. There are also four or five over girder foot and cattle bridges.

The line was originally laid with rails of 16 lbs. to the yard; these were afterwards replaced by 30-lb. rails, most of which have been in use 18 years.

They were found to be too light for the work, and are being substituted by double-headed rails of 48·66 lbs. to the yard, laid upon cross sleepers of larch 4 ft. 6 in. by 9 in. by $4\frac{1}{2}$ in. at intervals of 3 ft., excepting at the joints, where the centre bearing is 2 ft.

There is a framing fixed at every joint, which is arranged by placing two sleepers as longitudinals under the cross sleepers, spiked together.

The joints are fastened with socket fish-plates, which embrace the web and lower head of rail, and fastened together with fish-bolts and nuts.

The curves of the line are what may be described as parabolic. They are carefully laid out, having their extremities eased into the reversing curves or straight lines.

The cant or super-elevation of the outer rail is 3 inches in the maximum curves.

The points and crossings are made in the usual manner, and carefully constructed.

The permanent way is well ballasted, having interval water tables, and drained by side gutters in the cuttings.

The sidings at stations are from 200 to 400 yards in length, with mid space between lines of 4 ft. 6 in. and 6 ft.

There are no platforms at stations.

The stations have proper signals, according to the requirements of the Board of Trade for passenger lines, &c.

The Company have seven locomotives, one of which is equal in power to 440 tons of load, on a level, at a speed of 15 miles an hour; the usual load of the Fairlie engine over the average gradient of 1 in 92 is 90 tons, exclusive of engine, at from 12 to 20 miles an hour. Working pressure, 155 lbs.

This engine is at present in daily use, running two trains each day, with an "up" load varying from 75 to 107 tons, exclusive of weight of engine.

The lengths of trains with this engine are from 300 to 400 yards on the ascending gradients, with mixed train of passengers, goods, and empty slate trucks.

The other engines are four-wheel coupled tank engines, and are worked up to 160 lbs. pressure.

The cylinders of the four-wheel engine are $8\frac{1}{8}$ in. and 12 in. stroke with wheel base 4 ft. 6 in. and 5 ft., and that of the Fairlie engine $8\frac{3}{16}$ in. and 13 in. stroke, with wheel base of bogies 5 ft., and total wheel base of 19 ft.

There is much less wear and tear of permanent way and wheel flanges with the engine on the "Fairlie" principle, besides the advantage of equalized grip to rail of all the wheels, together with easier movement round the curves, without impact friction of the wheel flanges against the outer rail.

The "Fairlie" engine weighs $19\frac{1}{2}$ tons; four of the smaller engines 8 tons, and two 10 tons in steam; the diameter of the bogie wheels of the first-named engine is 2 ft. 4 in., and that of the smaller engines 2 ft.

The consumption of fuel by the Fairlie engine, as compared with the other engines, is 25 per cent. less for the same work done,

that is by working two engines together or separate. Performing a given duty, they will consume (say) 200 lbs. of fuel, whilst the Fairlie engine, doing the same duty, will consume only 150 lbs.

The Company have first, second, and third class carriages, close and open, some with longitudinal seats, and others with cross seats in the ordinary manner (see Diagrams Nos. 7, 8, and 9):—

Fig. 7.

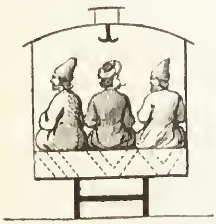


Fig. 8.

Fig. 9 (open).

The first named are 10 ft. long and 6 ft. 3 in. wide, the others are 9 ft. 9 in. long and 4 ft. 10½ in. wide, with elliptical springs.

The overhang of passenger carriages No. 7 from centre of rail is 1 ft. 5 in., but from end of axle is 10 in.

The goods trucks are made on similar principles to those on standard gauge lines.

The Coal trucks	weigh 19 cwt.	and carry 3 tons each
,, Goods trucks	18 ,,	,, ,, 2½ ,,
,, Bogie timber trucks	13 ,, each or 1 ton 6 ,, per pair	,, 9 ,,
,, Passengers' carriages (Nos. 8 and 9).	1 ,, 6 ,,	and carry of First Class 12, of Second ,, 14, and of Third ,, 14 persons
,, Passenger carriage (No. 7)	1 ,, 3 ,,	to .. 12 passengers
,, Slate wagons	19 ,,	.. 3 tons
,, ,, ...	13 ,,	.. 2 ,,

The wheels are 1 ft. 6 in. diameter, of cast iron, and tyred with Low Moor Iron.

The wheel tyres of slate trucks run from seven to nine years without requiring to be re-turned on lathe.

D

The distance between centres of wheels (or wheel base) of the various carriages, &c., is as follows :—

	ft.	in.		ft.	in.
Passenger carriages	5	0	and	5	6
Goods trucks	5	6			
Coal trucks	5	6			
Bogie timber trucks	3	0			
Slate wagons	2	11	and	3	1
„ „ (large)	4	1			
Slab trucks	5	0			

The lengths of journals are $3\frac{1}{2}$ to $4\frac{1}{4}$ in.

The carriages and trucks have single central buffers and couplings.

The following is a table of the rolling stock :—

Total numbers of locomotives	7	(Three generally in steam.)
„ „ Passenger carriages	14	
„ „ Quarrymen's carriages ..	32	
„ „ Goods, coal, and lime trucks	40	
„ „ Slate trucks	852	
Total of rolling stock ..	938	

	tons.	cwts.	qrs.
Mineral traffic for 1869	118,132	7	2
Goods „ „	18,600	0	0
Total gross weight hauled (exclusive of engines)	241,617	0	0
Number of passengers, 97,000.			

There is no night traffic and no Sunday trains.

The train mileage, 45,619. The number of extra miles run by engines over Traeth-mawr embankment, and at stations exclusive of the above, 4695. Total, 50,314 miles.

The Company are at present limited by the Board of Trade to a speed not exceeding 12 miles an hour, but I have, since adopting the Fairlie engine, made experiments with trains at 30 and 35 miles an hour with ease and safety, and without heating the bearings of locomotives or carriages.

The line being originally made as a Horse Railway to 2 ft. gauge, there was no alternative but to adopt that gauge on converting it into a Locomotive Passenger Railway.

The following tables (A, A 1, B, and C) show the weight, carrying capacity, cost, &c., of rolling stock, and working expenses, on the Festiniog Railway.

TABLE A.

TABLE showing the WEIGHT of TRAIN generally taken by the "FAIRLIE" ENGINE, together with its COST and CONSUMPTION of FUEL, as compared with one of our best 10-ton TANK ENGINES, and PROPORTION of PAYING and UNPAYING WEIGHT HAULED, taking the UP and DOWN JOURNEY, that is, including the RETURN EMPTY GOODS and SLATE TRUCKS (see Note *).

DESCRIPTION.	Weight of Locomotive Engine in Steam, and Tare Weight of Carriages, &c.	Number of Passenger Carriages, &c. Up (same Down).	Number of Passengers in Carriages. Up (same Down).	Weight of Passengers and Goods. Up.	Weight of Carriages, Trucks, and Load of Passengers. Up.	Entire Length of Train in motion, including Engine.	Cost of Carriages, Trucks, and Locomotive.	Total Cost of Carriages, Trucks, and Locomotive in Train.	Weight of Passengers and Slates. Down.	Weight of Carriages, Goods Wagons, and Slate Trucks. Down.	Total Weight of Passengers, Carriages, Goods Wagons, Slates, and Trucks. Down.	Total Weight of Passengers, Goods, and Slates. Up and Down.	Total Tare Weight of Carriages, Goods Wagons, and Slate Trucks. Up and Down.	Total Gross Weight of Train, Up and Down, exclusive of Engine.	Total Gross Weight of Train, Up and Down, inclusive of Engine.	Total Mean Weight of Train, Up and Down, exclusive of Engine.	Consumption of Fuel per ton per mile on Gross Weight of Train, exclusive of Engine.	Proportion of Paying to Unpaying Weight hauled, taking the Up and Down Journey, exclusive of Engine.	Proportion of Paying to Unpaying Weight hauled, taking the Up and Down Journey, inclusive of Engine.	Total capital cost of Railway per mile.	Cost of Rolling Stock per mile of Line.	Total Earnings of Line for year ending 1859.	Total Working Expenses.	Percentage of Working Expenses to the Gross Receipts.	Receipts per Train mile (average for the year).	Expenses per Train mile (average for the year).	Maintenance of Line per mile per annum (Old Permanent Way).
	t. c. q.			t. c. q.	t. c. q.	feet.	£.	£.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	lbs.			£.	£.	£.	£.	Per cent.	s. d.	s. d.	£.
1 "Fairlie" Engine in Steam	19 10 0	..	..	..	..	..	2,000																				
1 First-class Carriage	1 3 2		..	..	..	..	111	..	..	1 3 2																	
2 Second ditto ..	2 7 0	6	72	4 17 2	11 18 2	..	184	..	4 17 2	2 7 0	11 18 2																
3 Third ditto ..	3 10 2		..	..	..	1,203	255	5,096	..	3 10 2																	
1 Guard's Brake Van	1 13 3	1	..	Passengers' Luggage. 0 18 0	2 11 3	..	68	..	Passengers' Luggage. 0 18 0	1 13 3	2 11 3	251 0 0	173 14 2	424 14 2	463 14 2	212 7 1	†0·45	1·444 Paying to 1 Unpaying.	1·180 Paying to 1 Unpaying.	5,378	2,000	23,676	10,518	‡44½%	10 4½	‡4 7¼	83
6 Goods Trucks ..	5 6 2	6	..	15 0 0	20 6 2	..	192	..	..	5 6 2	Empty. 5 6 2																
112 Slate Wagons .	72 16 0	112	..	..	Empty. 72 16 0	..	2,286	..	224 0 0	72 16 0	296 16 0																
2 Brakesmen and Guard	..	..	3	0 4 2	0 4 2			Rolling Stock made by the Company at their own Works (with the exception of Locomotives); and this sum represents the cost price to the Company.	0 4 2	..	0 4 2																
	86 17 1	125	75	21 0 0	107 17 1				230 0 0	86 17 1	316 17 1																
																	Which includes Standing at Stations, but does not include Shunting.			Which includes two renewals of Permanent Way and reconstruction of considerable portions of Line for Passenger Railway, including half a mile of Tunnel, Foundry Works, and Wharves.			See Note ☞			This expense per mile includes large sums which properly should not be charged to the Train miles on our own length of line. (See explanation, page 38.)	On completion of New Permanent Way a considerable reduction will occur in this item.

* In giving the net tons hauled, the same number of passengers are given coming down as going up: goods as going up only; and the slate wagons as returning down always full.

† The consumption of fuel embraces an excess elevation to overcome on the up journey of 350 feet, supposing that the speed of down journey by gravity was at 20 miles an hour, *without application of brakes*, hence a saving of one-half in consumption of fuel would occur with the same loads by the reduced average inclination of 1 in 184, instead of the existing average inclination of 1 in 92.

‡ There being only one "Fairlie" engine on the line, and this worked in combination with the four-wheeled engines, a comparison of working expenses cannot be shown, and are here given as in Table A 1.

[*To face page* 34.]

TABLE A 1.

TABLE showing the WEIGHT of TRAIN generally taken with one of our best 10-ton TANK ENGINES, together with its COST and CONSUMPTION of FUEL, as compared with the "FAIRLIE" ENGINE, and the PROPORTION of PAYING to UNPAYING WEIGHT HAULED, taking the UP and DOWN JOURNEY, that is, including the RETURN EMPTY GOODS and SLATE TRUCKS (see Note *).

DESCRIPTION.	Weight of Locomotive Engine in Steam, and Tare Weight of Carriages, &c.	Number of Passenger Carriages, &c. Up (same Down).	Number of Passengers in Carriages. Up (same Down).	Weight of Passengers and Goods. Up.	Weight of Carriages, Trucks, and Load of Passengers. Up.	Entire Length of Train in motion, including Engine and Tender.	Cost of Carriages, Trucks, Locomotive, and Tender.	Total Cost of Carriages, Trucks, Locomotive, and Tender, in Train.	Weight of Passengers and Slates. Down.	Weight of Carriages, *Goods Wagons, and Slate Trucks. Down.	Total Weight of Passengers, Carriages, Goods Wagons, Slates, and Trucks. Down.
	t. c. q.			t. c. q.	t. c. q.	feet.	£.	£.	t. c. q.	t. c. q.	t. c. q.
1 Four-wheeled Tank Engine (in steam)	10 0 0	..	..	..	..	..	1,005				
1 Tender and Fuel ..	1 6 0										
1 First-class Carriage	1 3 2	..	..	..	..	..	111	..	..	1 3 2	
2 Second ditto	2 7 0	6	72	4 17 2	11 18 2	..	184	..	4 17 2	2 7 0	11 18 2
3 Third ditto	3 10 2	..	..	..	..	346	255	2,241	..	3 10 2	
1 Guard's Brake Van	1 13 3	1	..	Passengers' Luggage. 0 18 0	2 11 3	..	68	..	Passengers' Luggage. 0 18 0	1 13 3	2 11 3
4 Goods Trucks ..	3 11 0	4	..	10 0 0	13 11 0	..	128	..	..	3 11 0	Empty. 3 11 0
24 Slate Wagons ..	15 12 0	24	..	..	Empty. 15 12 0	..	490	..	48 0 0	15 12 0	63 12 0
2 Brakesmen and Guard	..	..	3	0 4 2	0 4 2			Rolling Stock made by the Company at their own Works (with the exception of Locomotives); and this sum represents the cost price to the Company.	0 4 2	..	0 4 2
	27 17 3	35	75	16 0 0	43 17 3				54 0 0	27 17 3	81 17 3

Total Weight of Passengers, Goods, and Slates. Up and Down.	Total Tare Weight of Carriages, Goods Wagons, and Slate Trucks. Up and Down.	Total Gross Weight of Train, Up and Down, exclusive of Engine and Tender.	Total Gross Weight of Train, Up and Down, inclusive of Engine and Tender.	Total Mean Weight of Train, Up and Down, exclusive of Engine and Tender.	Consumption of Fuel per ton per mile on Gross Weight of Trains, exclusive of Engine and Tender.	Proportion of Paying to Unpaying Weight hauled, taking the Up and Down Journey, exclusive of Engine and Tender.	Proportion of Paying to Unpaying Weight hauled, taking the Up and Down Journey, inclusive of Engine and Tender.	Total capital cost of Railway per mile.	Cost of Rolling Stock per mile of Line.	Total Earnings of Line for the Year 1869.	Total Working Expenses.	Percentage of Working Expenses to the Gross Receipts.	Receipts per Train Mile (average for the year).	Expenses per Train mile (average for the year).	Maintenance of Line per mile per annum (Old Permanent Way).
t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	lbs.			£.	£.	£.	£.	Per cent.	s. d.	s. d.	£.
70 0 0	55 15 2	125 15 2	148 7 2	62 17 3	†0·56	1·255 Paying to 1 Unpaying.	0·893 Paying to 1 Unpaying.	5,378	2,000	23,676	10,518	44½%	10 4½	4 7¼	83
					Which includes Standing at Stations, but does not include Shunting.			Which includes two renewals of Permanent Way and reconstruction of considerable portions of Line for Passenger Railway, including half a mile of Tunnel, Foundry Works, and Wharves.			See Note ☞			This expense per mile includes large sums which properly should not be charged to the Train miles on our own length of line. (See explanation, page 38.)	On completion of the New Permanent Way, a considerable reduction will occur in this item.

On Mondays and Saturdays there is one cheap train each of these days for taking quarrymen to and from the quarry works, when from three to four hundred are conveyed in open carriages (closed carriages being also attached), when the tare weight of train is less by 20 per cent. than the paying load, by calculating weight of train without weight of engine and tender.

The tare weight of mineral slate trucks is 13 cwt. each, and carrying capacity 2 tons. Others of 19 cwt. carry 3 tons, or with a train of 60 trucks a total weight of 39 tons to 120 tons paying load, or gross weight of 159 tons.

The daily slate traffic from the quarries down is equal to 380 tons, conveyed in 190 slate trucks. The weight of trucks being 123 tons, 10 cwt., or proportion of paying weight to non-paying weight of 3·076.

* In giving the net tons hauled, the same number of passengers are given coming down as going up; goods as going up only; and the slate wagons as returning down always full.

† This consumption of fuel embraces an excess elevation to overcome on the up journey of 350 feet, supposing that the speed of down journey by gravity was at 20 miles an hour *without application of brakes*, hence a saving of one-half in consumption of fuel would occur with the same loads by the reduced average inclination of 1 in 184, instead of the existing average inclination of 1 in 92.

TABLE B.

STATEMENT OF WORKING EXPENSES FOR THE YEAR ENDING JUNE, 1869.

	£ s. d.	£ s. d.
MAINTENANCE OF WAY—		
Wages	657 6 0	
Sleepers, keys, pins, &c.	284 8 0	
		941 14 0
Masonry		177 15 1
LOCOMOTIVE DEPARTMENT—		
Wages of foremen, fitters, cleaners, &c.	604 19 7	
Materials for repairs, &c., as per work account ..	402 0 8	
Oil and cotton waste	83 15 0	
Fuel used with engines, &c., and at locomotive shed	867 19 4	
		1,958 14 7
STAFF—		
Station masters, porters, signalmen, guards, brakesmen, engine drivers, and stokers, including clothing	2,707 3 11	
		2,707 3 11
SALARIES		604 16 8
REPAIRS OF ROLLING STOCK, &c.—		
(*m*) Repairs of slate trucks, as per works account		1,122 18 9
Repairs of carriages, vans, coals and goods trucks, &c.		440 16 4
(*n*) Grease and oil for carriages, trucks, and slate wagons		244 0 0
Coals used at works in repairs and offices		284 17 7
Absolute cost of working the traffic		8,482 16 11
MISCELLANEOUS—		
Parish rates		750 0 4
Passengers' duty		175 13 5
Income tax		255 6 10
General charges		854 8 9
Working expenses		£10,518 6 3

TABLE C.

		£ s. d.	
SPECIAL EXPENDITURE—			
Rents to the Tremadoc estate and Mr. Bankes ..		46 7 6	
Interest to executors of the late Sir Joseph Huddart on mortgage of 5170*l*.		258 10 0	
Tonnage for way leave over certain properties—			
Being over the Tremadoc estate lands at 1½*d*. a ton	£736 2 6		
Being over Mr. Bankes' lands at 1*d*.	554 18 6		
		1,291 1 0	
Interest on banking balance		599 13 1	
Rebate to Festiniog Slate Company		340 0 0	
			2,535 11 7
Total			£13,053 17 10

The foregoing items in Table C are quite irrelative of the working expenses of the line.

The Railway Company provide all mineral trucks for not only working their line, but in sufficient numbers for fifteen different slate quarries, over connecting quarry branch lines with the railway, which have no less than thirty-three self-acting inclined planes and fourteen miles of railways; such require about two-thirds more stock of slate trucks than if for the Company's line only. The wear and tear of these trucks off the Company's line is fully equal to two-thirds the cost marked (*m*), and half of item (*n*) in the above working expenses in Table B, making together a sum of 870*l.* 12*s.* 6*d.*, which in fact reduces the total working expenses to 9647*l.* 13*s.* 9*d.* On completion of the new permanent way, the maintenance of line for the first eight years will not require more than seven platelayers at 326*l.* 12*s.*, and renewal of sleepers 160*l.*, or an annual cost of 486*l.* 12*s.*, or 34*l.* 2*s.* per mile, exclusive of repairs of fencing.

	£	s.	d.
Total receipts for the year	23,676	12	10
Net revenue	10,622	15	0
Capital of the Company	36,185	10	0
Amount expended in works and paid out of revenue for improving the line and works at different times, and converting the line into a Locomotive Passenger Railway, including locomotive engines and rolling stock (allowed in Act of 1869)	50,000	0	0
Total	£86,185	10	0

The net revenue of 10,622*l.* 15*s.* on original capital of 36,185*l.* 10*s.* for the year, after deducting statement accounts of Tables B and C, equal to 29½ per cent., and on total capital of 1869 equal to 12½ per cent.

Explanation of the apparently high expense of working per train mile.

The working expenses as per Table B are 44½ per cent. of the receipts, but these should properly be only 31 per cent., for the following reasons.

The peculiarities attendant in working the traffic demand larger tolls to cover extraordinary expenses that the Company are subject

to over and above ordinary short lines, notwithstanding, by the Company's Act of 1869, the rates are the same as most other lines.

Firstly.—In working the traffic of this line, the traffic is one way for its whole length, and the down journey worked by gravity.

Secondly.—The elevation to overcome on continuous ascending gradients in the conveyance of all goods and of the empty slate trucks from the shipping port is limited by maximum gradient to nearly one-fourth load to that on a level, and to rather less than one-third load on the average gradient.

Thirdly.—The excess elevation to overcome at the limited speed of 12 miles an hour is fully 350 ft.; hence this excess tells in every way against the working of the traffic, and greatly increases the working expenses—the consumption of fuel is greater by at least one-half, the wear and tear is greater through continuous application of brakes on the down journey, as may be gathered from the necessity of every sixth slate truck in a train being a brake truck, besides extra wear of permanent way.

Fourthly.—The Company have to supply and keep in repair two-thirds more rolling stock of slate wagons than if the slate companies delivered their produce at the upper terminus, besides oil and grease and additional staff for and over same, which large stock is required over 33 inclined planes worked by machinery, and 14 miles of lines off the Company's railway. All slate wagons and slate trucks have to run over 27 miles of the Company's line loaded one way only besides the quarry lines off the railway, and 24 daylight and working hours being given for loading and unloading at quarries and wharves.

All goods are one way only, and that up the gradients, and the goods trucks return empty; hence from the foregoing observations, the reduction in annual working expenses, supposing that the line was one that had only half the elevation to surmount, and without the peculiar outside services that have to be performed beyond that of an ordinary line of railway, will be as follows:—

	£	s.	d.
1. Less by cost of fuel	430	0	0
2. ,, ,, of keeping slate wagons in repair off the Company's line, including grease	870	12	6
3. Interest on 12,000*l.* capital cost of surplus rolling stock at 5 per cent., and 5 per cent. for reimbursements of capital for 20 years' life of trucks	1,200	0	0
4. Less by cost of additional expenses in staff with the above slate wagons equal to $4\frac{1}{2}$ persons, at 46*l.* 11*s.* 6*d.* each	209	12	0
5. Less by cost in repairs of the needed surplus number of brakes for the slate and goods trains, 90*l.*; and that of additional wear and tear of line through their use, 80*l.*	170	0	0
(These items are approximate and low.)			
6. Less by difference in cost of repairs of Permanent Way by substitution of new Permanent Way ..	455	2	0
(Say nothing of reduced expenses in various ways.)			
	3,335	6	6
Working expenses	10,518	6	3
Working expenses with above deductions ..	£7,182	19	9

or 31 per cent. of the receipts, or 3*s.* $1\frac{1}{2}$*d.* per train mile, instead of 4*s.* $7\frac{1}{4}$*d.* as per Table A, but on the absolute miles run by engine in doing the work is 2*s.* $10\frac{1}{4}$*d.* and 4*s.* 2*d.*

The following are the rates charged by the Company:—

PASSENGERS.

	Per Mile. *d.*
1st Class single journey	1·71
,, ,, return	1·28
2nd ,, single	1·28
,, ,, return	0·96
3rd ,, single	1·07
,, ,, return	0·78
Quarrymen's Train each way	0·32

GOODS, &c.

	Per Ton per Mile.
Goods and parcels of every description up the gradients and empty returns taken on 14 miles	2·70

SLATES.

Slates including all the before-mentioned services and return empties (taken on 14 miles)	2·32
Receipts per ton per mile on gross weight of train (taken on 14 miles)	1·67
Expenses on the gross weight of trains taken on 10,518*l.* 6*s.* 3*d.* or	0·74
Do. do. if on 7,182*l.* 19*s.* 9*d.*	0·51

It would not be out of place here to give the amounts earned, and the cost of earning the same per Train Mile on some of the leading railways at home and abroad, in comparison to the Festiniog Railway.

TABLE OF COMPARATIVE EARNINGS AND EXPENSES.

London and North-Western. Half-year ending December, 1869.			Great Western. Half-year ending December, 1868.			North London. Half-year ending December, 1869.		
Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.	Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.	Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.
s. 5·77	s. 2·76	per cent. 47·84	s. 5·495	s. 2·671	per cent. 48·616	s. 5·42	s. 2·86	per cent. 52·7

Metropolitan. Half-year ending December, 1869.			East Indian. Half-year ending December, 1869.			Great Indian Peninsula. Half-year ending December, 1869.		
Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.	Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.	Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.
s. 5·19	s. 2·80	per cent. 54	s. 8·1	s. 4·0	per cent. 49·4	s. 9·8	s. 6·2	per cent. 63·2

Bombay and Baroda—India. Half-year ending December, 1869.			Festiniog. Half-year ending December, 1869.		
Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.	Gross Amount earned per Train Mile.	Expenses of Working per Train Mile.	Percentage of Working Expenses to Gross Receipts.
s. 11·6	s. 8·2	per cent. 70·7	s. 10·39	s. 4·60 Which include all the extraordinary charges enumerated on page 38.	per cent. 44·5

NARROW GAUGE RAILWAYS.

I do not recommend for light railways so small a gauge as 2 ft.; but, from my experience of working the 2 ft., I consider that 2 ft. 6 in. is ample for all purposes. The large amount of traffic that can be done with facility on lines of this kind is really surprising, particularly with the "Fairlie" engines; in fact, I may say fully 75 per cent. of that which can be effected on a 4 ft. 8½ in. gauge.

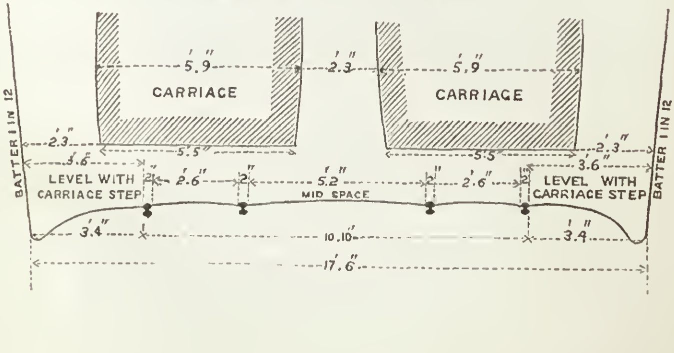
The Fairlie engines having only 2½ tons on a wheel, and these disposed in two bogies under the boilers, there is a great reduction of wear of engine tyres and of permanent way, which is reduced to a minimum. I have no hesitation in saying that the narrow gauge principle, worked on the Fairlie system of locomotives, having a permanent way well laid to 2 ft. 6 in. gauge, with good iron rails of not less than 55 lbs. to the yard, or steel rails of 50 lbs., with proper rail fastenings, will last about twenty years; but the sleepers will require renewing in from eight to ten years.

By the excessive weight thrown on one wheel of an engine on the standard gauge lines (being in some cases as much as 7½ tons) the rails are crushed out and not worn out, as is the case on lines of the small gauge principle.

The width of a single line in the clear at formation should be 9 ft. 6 in., and for a double line of way 17 ft. 6 in. For a double line the mid space between rails of two lines to be 5 ft. 2 in., as per following section :—

Fig. 10.

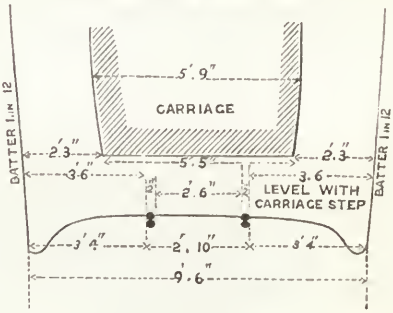
Section of Double Line.



A single line of railway in England of this type, through an ordinary country, would not cost much more than one-half of a standard gauge line of 4 ft. 8½ in., and a railway with double line of way about the cost of a single line of the standard gauge; but in a mountainous district the cost would be even less comparatively than above stated, consequent on the advantages that would be given by a narrow gauge in following the contour of the hill-sides, regardless of sharp curves (but by somewhat increased length of line), thus avoiding tunnels, viaducts, and heavy earthworks, which would be unavoidable upon the larger-gauge system.

Fig. 11.

Section of Single Line.



The paper, page 1, I read at the Inventors' Institute in 1865, soon after opening the Festiniog line as a locomotive passenger railway, as to the desirability of constructing lines on a narrow gauge system. Much has since been effected in various improvements of that line, resulting in showing the utility of narrow gauge railways, even beyond my anticipations, and most fully proving the effectiveness of the narrow gauge system.

Briefly the advantages of light (or narrow gauge) railways are as follows:—

1st. The large comparative saving in first construction.

2nd. The large proportion of paying load to non-paying or tare weight of train.

3rd. The great reduction of wear and tear of permanent way, through advantage gained by light rolling stock.

4th. Saving in reduced wear and tear of wheel tyres from reduced weight on each wheel.

5th. Large proportionate increased power of locomotives.

6th. Proportionate increased velocities gained by the light system.

7th. Greater economy in working traffic.

8th. Comparative increase in capabilities of traffic.

9th. Great advantages gained by application of the Fairlie system of locomotive engines in concentrated power, equalization of adhesion of all the wheels to the rails, economy from reduced friction on wheel flanges, reduction of wear and tear to the permanent way, great saving in fuel, and economy in wages for given powers secured.

I have made plans of carriages and trucks applicable for 2 ft. 6 in. gauge lines, outside skeleton plans of which are appended. They are arranged for ordinary traffic to carry various loads.

The overhang of passenger carriages from centre of rail to outside is 1 ft. $6\frac{1}{2}$ in., and from end of axle is $11\frac{1}{2}$ in.

The overhang of goods trucks, &c., from centre of rail is 1 ft. 5 in., and from end of axle $9\frac{1}{2}$ in.

		Tons.	Cwts.	Qrs.		
The First-class passenger carriage	weighs	1	10	2	to carry	12 persons.
„ Second „ „ „	„	1	10	0	„	16 „
„ Third „ „ „	„	1	10	0	„	16 „
„ Bogie carriage, with 7 compartments and van	weighs	5	10	0	„	54 „
„ Coal truck	„	1	6	3	„	$5\frac{1}{2}$ tons.
„ Goods or mineral truck	„	1	4	3	„	3 „ of grain, or 4 tons of lime, or 6 tons of ore.
„ Cattle truck	„	1	6	0	„	2 beasts.
„ Sheep „	„	1	4	0	„	12 sheep.

A train of such carriages and trucks can be run with ease and safety at 30 miles an hour on a line with maximum curves of 4 chains.

On the Festiniog Railway the diameter of carriage wheels is only 1 ft. 6 in., but for a 2 ft. 6 in. gauge should be 2 ft. diameter; and with a double bogie carriage with one first-class compartment, two second-class, and four third-class, with vans to carry fifty-four persons and luggage, the construction can be so arranged for the wheels to be 2 ft. 6 in. to 2 ft. 9 in. diameter. The diameter of engine-wheels coupled drivers to be 3 ft. 4 in.

The following is a comparative table of rolling stock, &c., of 2 ft. 6 in. and 4 ft. $8\frac{1}{2}$ in. gauge railways :—

TABLES D AND E, showing the CARRYING CAPACITY, WEIGHT of TRAIN LOAD, ENGINES, CARRIAGES of a PASSENGER TRAIN, on a 2 ft. 6 in. gauge railway, worked with the "Fairlie" engine, as compared with a standard gauge of 4 ft. 8½ in. worked with an ordinary six-wheeled passenger engine on an undulating railway, with maximum gradient of 1 in 100 of such length that the momentum is exhausted before reaching the summit, at a speed of 30 miles an hour.

TABLE D.—GAUGE, 2 FT. 6 IN.

DESCRIPTION.	Weight of Locomotive Engine and Tender, in Steam, and Tare weight of Carriages.	Number of Passengers' Carriages	Dead Weight of Engine and Carriages.	Number of Passengers in Carriages.	Total Number of Passengers in Train.	Weight of Passengers and Passengers' Luggage.	Weight of Carriages and Passengers' Load.	Total Weight of Train, exclusive of Engine and Tender.	Total Weight of Train, inclusive of Engine and Tender.	Entire Length of Train in Motion, exclusive of Engine.	Cost of Carriages, Locomotive, and Tender.	Proportion of Paying Weight to Non-paying Weight, exclusive of Engine and Tender.	Proportion of Paying Weight to Non-paying Weight, inclusive of Engine and Tender.
	t. c. q.		t. c. q.			t. c. q.	t. c. q.	t. c. q.	t. c. q.	feet.	£ s. d.		
1 "Fairlie" Engine, having no tender (in steam)	25 0 0	..	25 0 0	..	..	..	14 5 0				2500 0 0		
6 First-class Carriages ..	9 3 0	38		72		5 2 0	31 14 0				876 0 0		
12 Second ditto	18 0 0			192		13 14 0	52 17 0				1620 0 0		
20 Third ditto with one Brake	30 0 0			320		22 17 0					2460 0 0		
						Passengers' Luggage.		126 14 3	151 14 3	596	..	0·977	0·703
1 Guard's Brake Van ..	1 13 3	1	64 1 3	1	640	17 0 0	18 13 3				110 0 0		
Engine Driver, Stoker, and Guard	0 5 0						0 5 0						
1 Bogie Carriage, with 7 Compartments & Van	5 0 0	1		54 1		4 0 0	9 0 0				350 0 0		
	64 1 3					62 13 0					7916 0 0		

TABLE E.—GAUGE, 4 FT. 8½ IN.

DESCRIPTION.	Weight of Locomotive Engine and Tender, in Steam, and Tare weight of Carriages.	Number of Passengers' Carriages	Dead Weight of Engine and Carriages.	Number of Passengers in Carriages.	Total Number of Passengers in Train.	Weight of Passengers and Passengers' Luggage.	Weight of Carriages and Passengers' Load.	Total Weight of Train, exclusive of Engine and Tender.	Total Weight of Train, inclusive of Engine and Tender.	Entire Length of Train in Motion, exclusive of Engine.	Cost of Carriages, Locomotive, and Tender.	Proportion of Paying Weight to Non-paying Weight, exclusive of Engine and Tender.	Proportion of Paying Weight to Non-paying Weight, inclusive of Engine and Tender.
1 Four-wheeled coupled Locomotive (in steam)	27 0 0		45 0 0	..	..	..	..	..	..	..	3000 0 0		
Tender and Fuel	18 0 0												
2 First-class Carriages (3 compartments).. ..	12 0 0			36		2 11 0	14 11 0				670 0 0		
4 Second-class Carriages (4 compartments) ..	26 0 0			128		9 2 0	35 2 0				1008 0 0		
7 Third-class Carriages (3 with 5 compartments, and 4 with 4 compartments).. ..	47 0 0			310		22 3 0	69 3 0				1638 0 0		
			102 17 10	1	538	Passengers' Luggage.		155 1 0	200 1 0	398		0·507	0·353
1 Guard's Brake Van ..	5 0 0	1				14 0 0	19 0 0				200 0 0		
Engine Driver, Stoker, and Guard	0 5 0						0 5 0						
1 Bogie Carriage, with 7 Compartments & Van	12 12 0	1		62 1		4 8 0	17 0 0				600 0 0		
	102 17 0					52 4 0					7116 0 0		

TABLES F AND G, showing the CARRYING CAPACITY, WEIGHT of TRAIN LOAD, ENGINES and TRUCKS of a MINERAL and GOODS TRAIN, on a 2 ft. 6 in. gauge railway, worked with a "Fairlie" engine, as compared with a standard gauge line of 4 ft. 8½ in. worked with an ordinary engine, on an undulating railway with maximum gradients of 1 in 100, of such lengths that the momentum is exhausted before reaching summit, at a speed of 15 miles an hour.

TABLE F.—GAUGE, 2 FT. 6 IN.

DESCRIPTION.	Weight of Locomotive Engine and Tender in Steam, and Tare Weight of Trucks.	Number of Trucks in Train.	Dead Weight of Engines and Trucks.	Weight of Minerals and Goods in Train.	Weight of Trucks, Minerals, and Goods.	Total Weight of Train, exclusive of Engine and Tender.	Total Weight of Train, inclusive of Engine and Tender.	Length of Train in Motion, inclusive of Engine and Tender.	Cost of Locomotive, Tender, and Trucks.	Proportion of Paying Weight to Non-paying Weight, exclusive of Engine and Tender.	Proportion of Paying Weight to Non-paying Weight, inclusive of Engine and Tender.
	t. c. q.		t. c. q.	t. c. q.	t. c. q.	t. c. q.	t. c. q.	feet.	£ s. d.		
1 "Fairlie" Engine	26 0 0	..	26 0 0	..	55 2 1	181 13 2 With Steam pressure 170 lbs. The working load 133 tons, with pressure varying from 140 to 160 lbs.	207 13 2	485	2500 0 0	2·986	1·900
13 Goods Trucks	16 2 1	36	45 11 2	39 0 0	102 11 1				598 0 0		
15 Coal and Lime Trucks ..	20 1 1			82 10 0	7 16 0				712 0 0		
3 Cattle Trucks	3 18 0			3 18 0	4 2 0				175 10 0		
2 Sheep Trucks	2 8 0			1 14 0	10 12 0				115 0 0		
2 Timber Trucks, as Bogies	1 12 0			9 0 0	1 10 0				92 0 0		
1 Brake Van	1 10 0			..					100 0 0		
	45 11 2			136 2 0					4293 0 0		

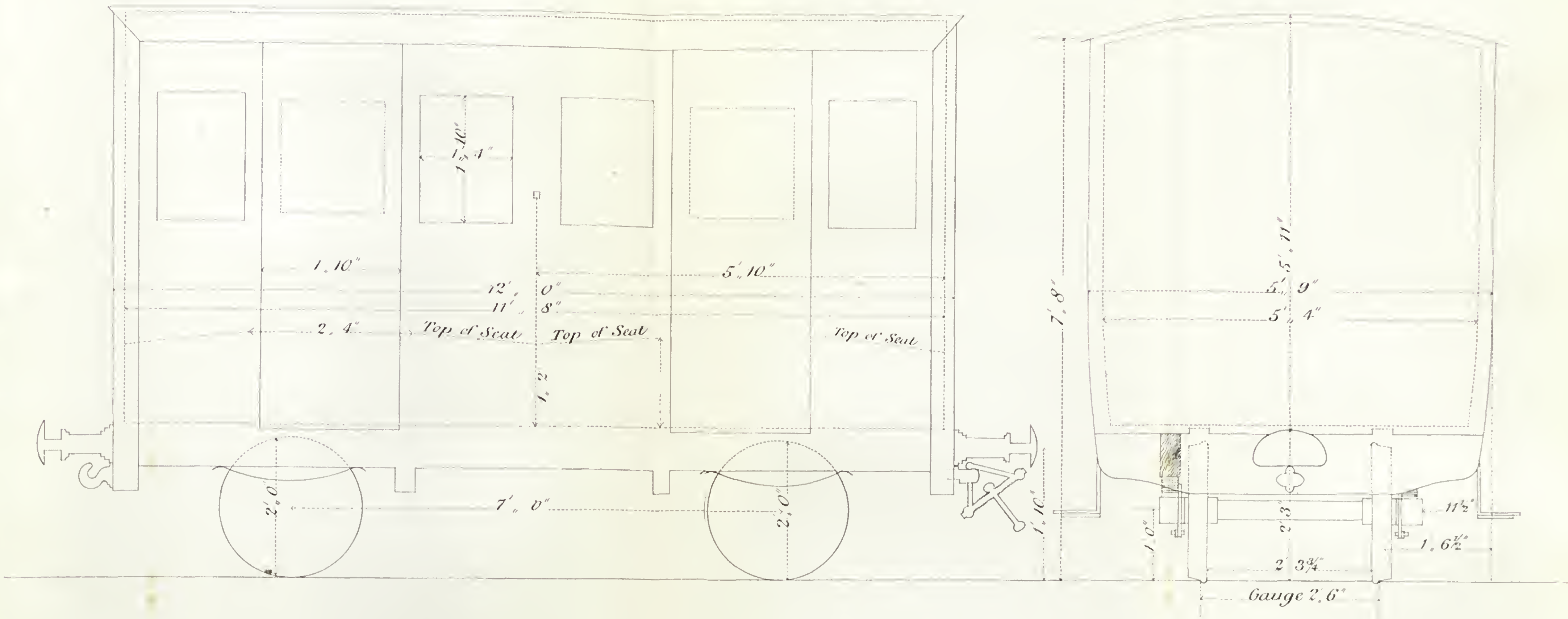
TABLE G.—GAUGE, 4 FT. 8½ IN.

DESCRIPTION.	Weight of Locomotive Engine and Tender in Steam, and Tare Weight of Trucks.	Number of Trucks in Train.	Dead Weight of Engines and Trucks.	Weight of Minerals and Goods in Train.	Weight of Trucks, Minerals, and Goods.	Total Weight of Train, exclusive of Engine and Tender.	Total Weight of Train, inclusive of Engine and Tender.	Length of Train in Motion, inclusive of Engine and Tender.	Cost of Locomotive, Tender, and Trucks.	Proportion of Paying Weight to Non-paying Weight, exclusive of Engine and Tender.	Proportion of Paying Weight to Non-paying Weight, inclusive of Engine and Tender.
1 Six-wheeled Coupled Goods Engine (in steam).. ..	36 0 0	..	56 0 0	..	..	..	..	..	3000 0 0		
1 Tender and Fuel	20 0 0										
5 Goods Trucks	22 10 0	19	88 16 0	35 0 0	57 10 0	220 0 0 With Steam pressure 170 lbs. The working load 161 tons, with pressure varying from 140 to 160 lbs.	276 0 0	435	342 10 0	1·477	0·906
7 Coal and Lime Trucks ..	32 13 0			70 0 0	102 13 0				479 10 0		
2 Cattle Trucks	10 8 0			7 16 0	18 4 0				197 0 0		
2 Sheep Trucks	10 0 0			3 8 0	13 8 0				201 0 0		
2 Timber Trucks, as Bogies	8 5 0			15 0 0	23 5 0				135 0 0		
1 Brake Van	5 0 0			..	5 0 0				180 0 0		
	88 16 0			131 4 0					4535 0 0		

PASSENGER CARRIAGE.

(For 2„ 6" Gauge)

First Class to Carry 12 Passengers,
Second and Third Class to Carry 16 Passengers.



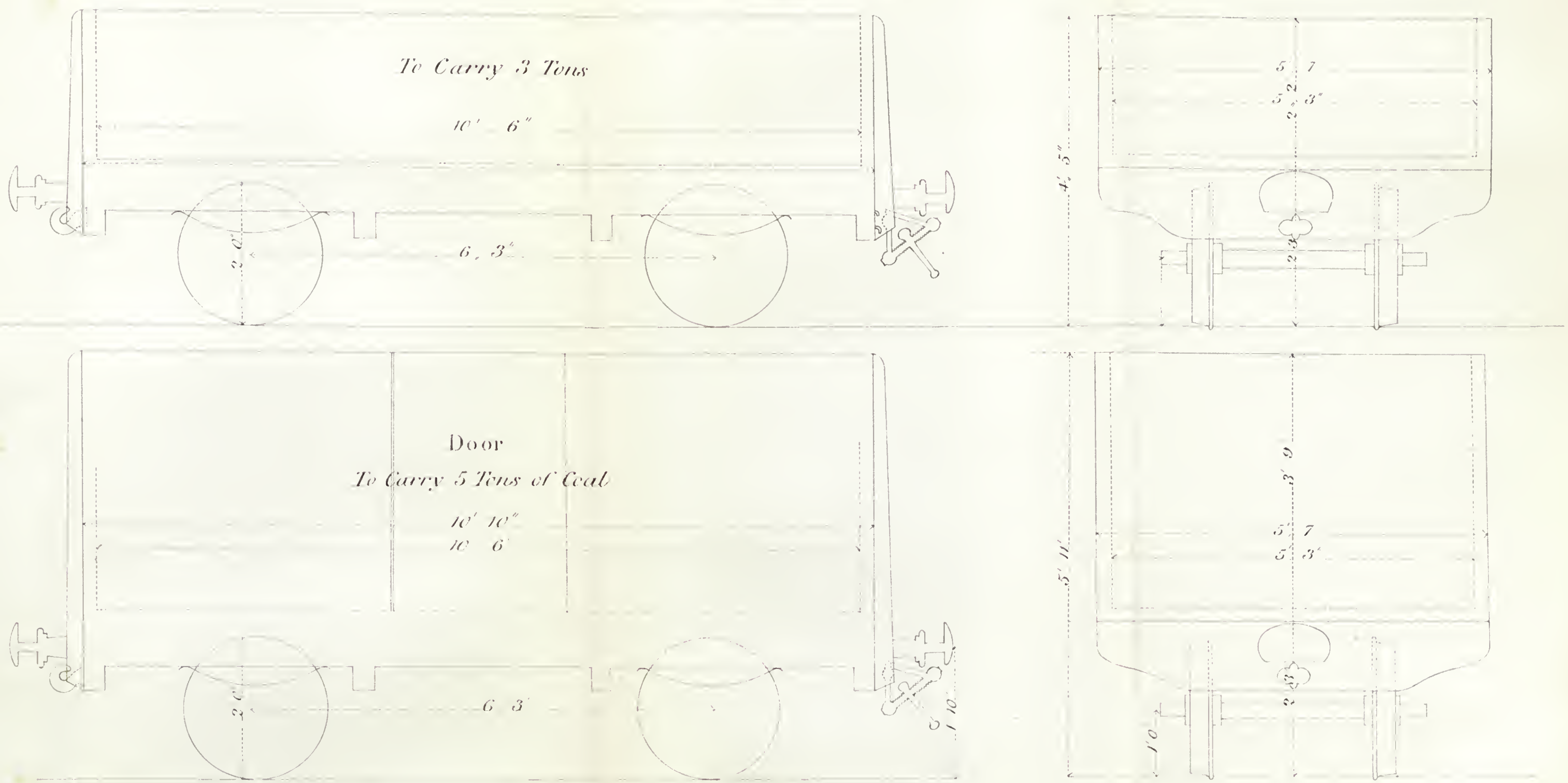
Scale ½ inch to the Foot.

Note. _ *To have the usual Lamps in Roof.*

WATERLOW & SONS, LITHOGRAPHERS, LONDON.

Goods Wagon and Coal Truck

For 2' . 6" Gauge



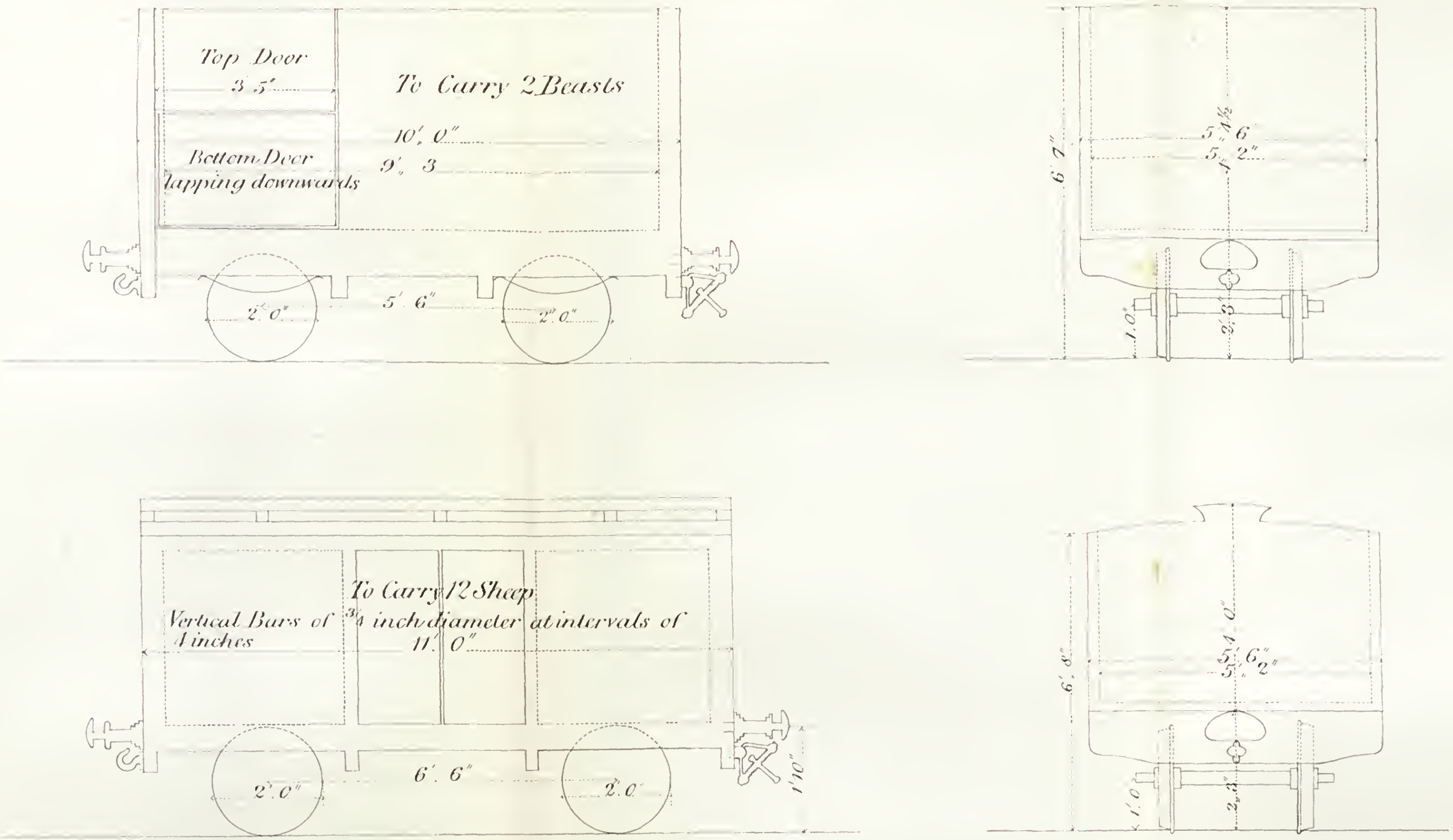
Scale ½ inch to the Foot.

WATERLOW & SONS, LITHOGRAPHERS, LONDON

Skeleton Plan.

CATTLE TRUCK AND SHEEP TRUCK

For 2' ,, 6" Gauge.



Scale 1/3rd inch to the Foot.

WATERLOW & SONS, LITHOGRAPHERS, LONDON

The following Noblemen, Directors, Managers, and Engineers of Railways, were present at the EXPERIMENTS AT PORTMADOC.

His Grace the Duke of Sutherland, accompanied by Count Széchenyi, of Hungary.

Representing Russia.

Count Alexis Bobrinskoy, President of Imperial Russian Commission.

Count Zamoyski, accompanying Count Bobrinskoy.

Count Berg, " " "

Colonel Statkowski, Russian Imperial Engineer.

Professor Saloff, Russian Institute of Imperial Engineers, and Member of the Commission.

M. Roehrberg, Chief Engineer and Manager of the Nigne Moscow Railway, and Member of the Commission.

M. Schuberski, Locomotive Superintendent of the Worsnesch Rostow Railway, and Member of the Commission.

M. Kislinski, Russian Imperial Engineers, Inspector of Karchof Crementchay Railway.

M. Von Desen, Imperial Russian Engineer, Seratoff Railway.

M. Sementechymoff " " "

M. Sachnoffski, " " "

Representing the India Office.

Lieut.-General Sir William Baker, R.E., K.C.B.

Mr. W. T. Thornton, Corresponding Secretary, Public Works, Railway and Telegraph Department, India Office.

Mr. Juland Danvers, Government Director of Indian Railways.

Representing Board of Trade.

Captain Tyler.

Representing France.

M. Genty, President of the La Vendée Railway.

M. Duval, Engineer of La Vendée.

M. Kremer, Directeur, Poti and Tiflis Railway.

Representing Sweden.

M. Sandberg, Engineer to Swedish Government.

Representing Norway.

M. Pihl, Chief Engineer, Norwegian Railway.

Representing Switzerland.

M. Carl Burckhardt, Engineer.

Representing North Germany.

Mr. Mulvany.

Mr. C. E. Spooner, Engineer of the Festiniog Railway.

Mr. Livingston Thompson, Managing Director, Festiniog Railway.

Mr. Fleming (Star of India), of the firm of Smith, Fleming, & Co., Bombay.

Mr. George Allen, C.E.

Mr. Power, Vice-Chairman, Poti and Tiflis Railway.

Mr. G. B. Crawley, Contractor for the Poti and Tiflis, and Mexican Railways.

Mr. James Samuel, C.E., Director of the Railway Working Association.

Mr. Tolmé, " " " "

Mr. A. P. Hobson, Secretary, " "

Mr. E. S. Dallas.

Mr. Cargill, C.E.

Mr. Preston, C.E.

Mr. Preston, Solicitor, London and North-Western Railway.

Mr. Patchett, Superintendent, London and North-Western Railway in Wales.

Mr. Elias, General Manager, Cambrian Railway.

Mr. Broughton, " Mid Wales.

Mr. Walker, Locomotive Superintendent, Cambrian Railway.

Mr. Roberts, Engineer, Brecon and Merthyr Railway.

Mr. Caulfield, " Neath and Brecon.

Mr. Henshaw, General Manager, Brecon and Merthyr.

Mr. Owen, Engineer, Cambrian Railways.

Mr. J. S. Spooner, Engineer, Talyllyn Railway.

The Fairlie Engine on a 1·11½ Gauge, commonly called 2-feet Gauge.

The Result of Experiments on the Festiniog Railway on February 11 and 12, 1870.

February 11.—Started from Portmadoc with the "Little Wonder," or Fairlie Engine, and

	Tons.	Cwts.	Qrs.
90 Slate wagons	57	10	0
7 Passenger carriages and van	13	10	0
57 Passengers	4	0	0
	75	0	0
Engine	19	10	0
	94	10	0

Engine double bogie, $8\frac{3}{16}$ in. cylinders × 13 in. stroke ..
Wheels, 2 ft. 4 in. diameter .. ..
Pressure of steam average, 150 lbs. .. ..
Steepest gradient, 1 in 74 .. ..
Sharpest curves, $1\frac{3}{4}$ chain .. ..

The total wheel base is 19 ft., the wheel base of each bogie is 5 ft., and the total length over all, 27 ft.

On sharpest curves and steepest gradients, with engine in full gear, average speed 14½ miles, exclusive of time lost in stopping and starting. Length of train, 854 feet.

Generally observed that even on curves of 1¾ chain radius, and at maximum speed, that there was very little perceptible oscillation or movement on the engine or in the carriages, and by no means such as is usually felt even on comparatively easy curves on ordinary railways, and less at high speed than at low speed. The super-elevation of the outer rail on the sharpest curves was 3 inches.

February 12.—Experiments with "Little Wonder," 19½ tons; "Welsh Pony," 10 tons; "Mountaineer," 8 tons; to test steadiness of running on Traeth-mawr embankment.

On the "Welsh Pony" and "Mountaineer" strong vertical oscillation with less lateral oscillation.

On the "Little Wonder," when riding on the foot-plates, no perceptible vertical or lateral oscillation; but a smooth floating movement when riding on the bogie frames, slight lateral oscillation, but less than on the other engines.

The oscillation of the "Fairlie" Engine being confined to the

bogie, the influence of impact on the rails from the flanges of the wheel was far less than in the case of the "Pony" or "Mountaineer," the whole weight of these engines being brought to bear, in the course of their oscillations, upon the rails.

In all the above cases the speed was confined to 10 or 12 miles an hour on a straight line on a gradient of 1 in 1200, and the line was laid with rails weighing only 30 lbs. to the yard, not fished at the joints.

The "Welsh Pony" engine, weighing 10 tons, with cylinders $8\frac{1}{8}$ diameter × 12 in. stroke, and with wheels 2 ft. diameter, took 50 wagons loaded with slate from Portmadoc to the engine house, and stopped on a gradient of 1 in 85 unable to proceed farther with 160 lbs. to the square inch of pressure, and mounted 1 in 85 with 140 lbs. pressure of steam in starting, and 130 lbs. after running about a quarter of a mile, when she was stopped to return.

	Tons.	Cwts.	Qrs.
Weight of 50 wagons loaded	123	10	0
Passengers	3	10	0
	127	0	0
Engine	10	0	0
	137	0	0

	Tons.	Cwts.	Qrs.
The "Welsh Pony" then took 25 wagons, weighing ..	59	7	2
Passengers	3	10	0
	62	17	2
Engine	10	0	0
	72	17	2

The same engine, when tried with 30 wagons, could not start on a gradient of 1 in 85, but the engine wheels did not revolve, there was therefore no want of adhesion. The load having been reduced to

	Tons.	Cwts.	Qrs.
26 wagons, weighing	62	6	0
Passengers	1	10	0
	63	16	0
Engine	10	0	0
	73	16	0

with an average pressure of 150 lbs. to the square inch, the

"Pony" took them up 1 in 85 for a quarter of a mile at 5 miles an hour, till she was purposely stopped.

The "Little Wonder" left Portmadoc the same afternoon with 72 loaded wagons, weighing—

	Tons.	Cwts.	Qrs.
Slate trucks	138	17	2
Empty wagons	43	13	0
Passengers	4	0	0
	186	10	2
Engine	19	10	0
	206	0	2

Started with 165 lbs. of steam pressure, and ran to the engine-house and up the above gradient of 1 in 85, and was purposely stopped with steam at 125 lbs. and a low fire, through the misapprehension of the engine driver; she was then backed down to the locality from which the "Pony" had started with 26 wagons, and the fire having been made up, and steam raised to 170 lbs., she started freely, occasionally slipping, attained to a speed of 5 miles an hour with the 72 wagons, and after running about a quarter of a mile she was increasing speed on a gradient of 1 in 100, when she was purposely stopped, with steam pressure of 170 lbs. to the inch.

In the above experiments the shorter trains were standing when they were started, or attempted to start, partly on a curve of 4½ chains; and in the last experiment with the "Little Wonder," the train having been longer, it stood partly on a curve of 4½ chains radius, and partly on a reverse curve of 8 chains radius. The length of this train was 648 feet.

The weather was fine, with a strong cold wind blowing against the trains, and the rails were in a remarkably good state for adhesion.

The slate wagons had no springs; the diameter of their wheels was 1′ 6″, and that of the journals was 4¼ inches.

(Signed) SUTHERLAND,
COUNT ALEXIS BOBRINSKOY,
W. E. BAKER,
W. J. THORNTON,
H. W. TYLER,
JULAND DANVERS.

Second Series of Experiments with the Fairlie Engine on the 1 ft. $11\frac{1}{2}$ in. gauge.

The result of an experiment on the Festiniog Railway on the 16th February, 1870, with the "Little Wonder" (Fairlie engine).

Length of engine	27 ft.
Weight of engine in steam	$19\frac{1}{2}$ tons.
Diameter of cylinder	$8\frac{3}{16}$ in.
Length of stroke	13 in.
Two four-wheel bogies.	
Diameter of wheels	2 ft. 4 in.
Wheels coupled in each bogie.	
Wheel base of each bogie	5 ft.
Total wheel base	19 ft.

Description of Load.

	Tons.	Cwts.	Qrs.
22 Wagons of coal	64	18	0
21 Wagons of slates	49	3	1
2 Bogie timber trucks, carrying timber in length 42 ft.	4	18	2
Passengers' weight	1	1	2
2 Empty trucks between timber bogies	1	4	1
1 Workmen's carriage	0	12	0
Engine	19	10	0
Total	141	7	2

Length of train, with engine, 407 ft.

The whole distance to be run over from Portmadoc to Dinas, $13\frac{1}{4}$ miles, having a total rise from sea level of 703 ft., with maximum gradient of 1 in 74, and average gradient of 1 in 92 for $12\frac{1}{4}$ miles. The Traethmawr embankment, near Portmadoc, of 1 mile in length, being practically level; the maximum curves, $1\frac{3}{4}$ chain, average curves being 6, 7, and 8 chains; the whole of the line being composed of a succession of curves, with the exception of the before-named embankment, and three or four other short portions.

The train started from Portmadoc at 5.41 P.M. At Penrhyn Station 5.58, without stopping there.

Arrived at Hafodllyn Station at 6.18, where it stopped $8\frac{1}{2}$ minutes.

Started at $6.26\frac{1}{2}$; arrived at Dduallt Station (watering place) at 6.40; stopped 15 minutes; on account of water being frozen, the tank could not be filled in the usual time.

The train reached the long tunnel at 7.2 P.M., through which it passed in 2 minutes 10 seconds (length of tunnel 730 yards). Ran up to Tanygresiau Station, at which it arrived at 7.9; passed it slowly without stopping, arriving at Dinas at 7.15, having made the entire journey in 1 hour 34 minutes, including stoppages, or exclusive of stoppages, 1 hour 10½ minutes.

Maximum speed 15 miles an hour.

Average speed 11¼ ,,

The engine during the journey from Portmadoc to Hafodllyn never slipped.

On starting from Hafodllyn Station a slight slipping occurred (the train being on a curve of 4 chains with an inclination of 1 in 110), the rails being wet and greasy.

Slight slipping on starting from the watering place at Dduallt.

The engine slipped three times in passing through the tunnel, the rails being wet throughout.

Considerable slipping took place at the junction of Branch Line, this place being always wet and greasy owing to the slate trains waiting for the down passenger-train.

The pressure of steam ranged from 160 to 180 lbs., at which latter pressure the train started, the pressure being on one occasion only 145 lbs. for a quarter of a mile; average pressure, 175 lbs.

The entire journey was run throughout by the engine in "two-thirds gear."

There was a head wind during the whole of the journey, such being very strong in some parts of the line against the train.

(Signed) LIVINGSTON THOMPSON,
C. E. SPOONER,
COUNT ALEXIS BOBRINSKOY,
T. ROEHRBERG,
PROFESSOR SALOFF,
R. VANDESEN,
J. SEMENTSCHINOFFE.

THIRD SERIES of EXPERIMENTS with the FAIRLIE ENGINE on the 1·11½ gauge, under the superintendence of the PRESIDENT and ENGINEER of the LA VENDÉE RAILWAY of France, 17th February, 1870.

Started from Portmadoc with a train of 140 empty slate wagons and 7 loaded coal wagons, gross load 100 tons 16 cwt. 2 qrs., length of train 1323 feet, and proceeded to Dinas, the upper end of the Festiniog Railway. The maximum speed was 16½ miles, the average 12½ miles.

On the return journey the speed attained was 30 miles an hour, over many portions of the road the average speed being 25 miles an hour.

On the 18th the line was inspected by Col. Statkowski, Russian Government engineer, specially sent over by the Grand Duke Michael from Moscow, and E. Preston, Esq., C.E. A train of 81 tons 11 cwt. 1 qr., exclusive of weight of engine, was taken up by the "Little Wonder" at a speed varying from 13 miles to 22 miles an hour—pressure, from 145 lbs. to 160 lbs.

EXPERIMENTS MADE 8TH JULY, 1870.

Colonel Dickens and Colonel Strachey, with Mr. John Fowler and Mr. Rendell, arrived at Portmadoc, and on Mr. Spooner's invitation, after their return from examining the line, these gentlemen attended the experiments, which took place as follows:—

Experiment No. 1.

This was made with the "Little Giant" and "Welsh Pony," coupled together, and attached to a train made up as follows:—

	Tons.	Cwts.	Tons.	Cwts.	Qrs.
75 Loaded slate trucks, weighing			183	13	3
8 Empty " "			5	0	3
Passengers			1	0	0
"Little Giant"	10	0			
Tender	1	2			
"Welsh Pony"	10	0			
Tender	1	6			
			22	8	0
Gross load			212	2	2

Both engines started from near the bridge at Portmadoc at 4.52 P.M., with the steam pressure in each at 150 lbs. The weather was very favourable, being warm and dry.

Both engines slipped much at starting, but on sanding five or six yards of rails, they both went off well.

At the middle of the embankment the "Little Giant's" pressure was 160 lbs., then it dropped to 155 lbs., and rose at far end of embankment to 160 lbs., after which it gradually increased, until the two engines were pulled up by the load, when it stood at 165 lbs.

The "Welsh Pony's" pressure fell to 142 lbs. at the far end of the embankment, and to 140 lbs. at the weigh-house; then a little beyond it rose to 144 lbs., and increased to 150 lbs., at which it stood when the two engines were pulled up by the load.

The speed of the train increased to the far end of the embankment, then gradually diminished as we got round the curve; and when the whole train was on the incline of 1 in 85·65 both engines began to slip, and slipped frequently over this and the next two gradients of 1 in 100 and 1 in 90·51, on which they were pulled up by the load, about 50 yards on the Portmadoc side of the Minfordd gate crossing.

The distance run from that port station was 1 mile 5 furlongs and 3 chains (nearly 1 mile of this distance being over the Traethmawr embankment, which is perfectly straight and nearly level), and the time occupied was twelve minutes, which gives an average of over $8\frac{1}{4}$ miles an hour.

Everything was done that could be done to get the utmost power out of these two engines; both were in good order, and their fires were strong and clear at starting, and it will be seen the boiler pressures were well maintained throughout.

With the regulators full open the engines made steam fast whilst their speed slackened on the inclines, and some time before they were pulled up they were enveloped in clouds of steam.

The train was allowed to drop down the inclines and run back to Portmadoc, and the "Little Wonder" was then attached to the train in place of the "Giant" and "Pony."

Experiment No. 2.

The train not having been shunted far enough down the line below the station, the "Little Wonder" stood opposite the water-tank, and the rails being always wet and greasy, she slipped considerably at starting.

At the first effort a link broke about twenty wagons from the front, and at the second, another of the adjoining wagons; after which, on sanding 6 or 7 yards of rail, she made an easy and good start, and rapidly increased in speed until beyond the curve at the far end of the embankment, when she gradually slackened over the inclines of 1 in 85·65 and 1 in 100 to a rate of about 10 miles an hour, at which speed she passed the point where the others were pulled up on the gradient of 1 in 90·51, and went half a mile beyond, continuing to do her work well.

At this stage it was quite evident that the engine had perfect command over its train, and on Mr. Spooner asking Mr. Fowler if he wished to proceed on farther, the latter expressed himself satisfied, and at his instance the engine was stopped.

Her steam pressure at starting was 160 lbs.; it rose to 162 lbs. and fell to 158 lbs. at the signal post on the embankment, after which it gradually increased to 165 lbs. at far end of embankment; 167 lbs. at weigh-house; fell to 160 lbs. at gate-crossing, to 157 lbs. at second gate-crossing, to 155 lbs., at which it stood when the engine was stopped.

The start was made at 5.45 P.M. and the stoppage at 5.55 P.M. The distance run was 2 miles 1 furlong and 3 chains, at an average rate of 13 miles an hour.

The fires were not so frequently stoked as those of the other engines.

When the engine was stopped, a conversation took place as to whether it could start the train from its state of rest on the incline, and on Mr. Rendell remarking that he did not think the engine could do it, Mr. Spooner was asked to try it.

Meantime the driver, concluding that the experiment was over and having only to return to the port, lowered his fires, and allowed the pressure to fall to 140 lbs., when the order to go-ahead was given; and this being observed, it was decided to raise the pressure to that at which it stood when the engine was stopped.

The rails were sanded for 5 or 6 yards, and with the gauge standing at 160 lbs. a good and easy start was made, and at an increasing speed for a quarter of a mile, when she was stopped at Mr. Fowler's request, the experiment being satisfactory.

When stopped on the first run the engine was at the head of the gradient of 1 in 90·51 on a curve of 15 chains, within 7 or 8 yards of 1 in 82·71; her second start was practically made on that incline, and on it she attained a speed of 5 or 6 miles an hour, and was increasing when stopped, the gauge then indicating a pressure of 170 lbs.

For the first second or so after starting, she slipped three times with one-fourth of the train still under the brake, after which she again slipped twice, but went away easily, as stated, at an increasing speed.

From Captain H. W. Tyler *to the* Board of Trade.

"Sir, "1, Whitehall, March 4, 1870.

"I have now the honour to report, for the information of the Board of Trade, that, in compliance with the instructions in your Minute of the 8th ultimo, I attended certain experiments on the 11th, 12th, 14th, and 15th ultimo on the Festiniog and Mid-Wales Railways.

"The object of these experiments was to test the capabilities of the Festiniog Railway, which has a gauge of rather less than 2 feet; and also the powers and comparative steadiness of double bogie engines, such as have been designed by Mr. Fairlie, both on the Festiniog Railway and on the ordinary gauge of 4 ft. 8½ in.

"The trials were made in the presence of various members of an Imperial Commission, under the Presidency of Count Alexis Bobrinskoy, who visited England for these special purposes, as well as of His Grace the Duke of Sutherland, and numerous others from various countries, including Major-General Sir William Baker, R.E., and Mr. Thornton and Mr. Juland Danvers from the India Office.

"I beg to enclose herewith detailed statements of the experiments, in the form of the original documents, drawn up by myself

in the presence of those who witnessed them, and containing descriptions of the engines employed.

"As regards the Festiniog Railway, they quite bore out what I stated in regard to it in my reports to the Board of Trade, six or seven years since, previously to its being opened for passenger traffic, and those contained in a paper which I subsequently read at the Institution of Civil Engineers. The amount of traffic which can be economically carried upon this little railway, and the speed at which it can be conveyed round curves which would be absolutely impracticable under the ordinary system of railway working, render it a most instructive example, showing how, by a reduction of gauge, adaptation of rolling stock, and judicious arrangements, cheap railways on narrower gauges may be advantageously constructed in our colonies, in foreign countries, and even in parts of the United Kingdom. The precise gauge in such cases should, however, be suited to the local circumstances of each particular locality, and must depend upon various considerations which it is not necessary here to detail.

"When the Festiniog Railway was first opened for passenger traffic, the Board of Trade, on my recommendation, made it a condition that the speed should be limited to 10 or 12 miles an hour. And this was done on account of the narrowness and lowness of the works, the condition of the permanent way, and the novelty of the system of applying locomotive power to so narrow a gauge. Since that time the permanent way has been materially improved, and the greater part of it has been relaid with heavier rails, fished at the joints. The system has also been thoroughly tested, and there appear to have been no accidents to passengers. But the narrowness and lowness of the works remain, and this is now the weak point of the line.

"At certain bridges on the line, and other places, extra height and width might, apparently, without so much difficulty or expense, be afforded, and the Company would do wisely in making such improvements, as far as practicable; but the enlargement of the tunnels, and of the width in certain other places, would, no doubt, be very costly.

"The speed appears to have been increased from time to time, as the permanent way has been improved, and it would now, I think, be only right to release the Company from the obligation which

was imposed upon them in this respect, on their first opening for passengers. As they have hitherto conducted the traffic with safety to the public for so many years, the question of speed might now properly be left to their own discretion, not with the idea that they are to run their passenger trains at the comparatively high speed of which the little line has so curiously shown itself to be capable, under the system of low centres of gravity, which has so wisely been adopted for the rolling stock, but with confidence that they will keep well within that speed, and allow ample margin for all contingencies, such as cannot always be foreseen, even under the most careful management.

"As regards Mr. Fairlie's double bogie engines, the experiments have shown, not only that the principle upon which they are designed,—1st, of reducing wear and tear and friction by the employment of the bogie system; 2nd, of conveniently accumulating the weight upon the wheels, so as to make all the wheels into driving wheels; and, 3rd, of providing engines which can run in either direction with equal safety,—are sound, but also that the narrower the gauge the more profitably they can be employed for through traffic.

"I have, &c.,
(Signed) "H. W. Tyler.

"The Secretary, Railway Department,
Board of Trade."

THE RAILWAYS OF THE FUTURE.

(Reprinted from 'The Times,' February, 1870.)

No. I.

"Many persons in England are apt to suppose that we have come to the end of railway extension. The country is so well furnished with railways, and their financial results are so disappointing, that people are naturally loth to contemplate any further experiments on the established system. We are most grateful to the shareholders who have been so good as to supply us with these admirable roads, which have gone far to change the character of our civilization; but there are not many of us who care to follow their example, and we cannot be surprised if they should themselves be unwilling to continue the sacrifice of their fortunes for our benefit. Still, those who are acquainted with the demand for railways in foreign lands, in our colonies, and even in many parts of our own country, must be aware that we are speaking literally when we say that railways are as yet but in their infancy. There is an enormous demand for them in India, for instance; and yet every man of common sense must admit that, judging by all English examples, it is perfect madness to construct them on the received system, which means ruinous expenditure and dead loss. So thoroughly is the need of a great revolution in railway construction perceived, that some months ago, we had to make the startling announcement that the Governor-General of India, dissatisfied with the slow progress and excessive cost of railways in his dominion, had actually sent to the United States for engineers who might confer with him as to the introduction of a more effectual and economical system—as if this were beyond the capacity of English engineers; and we propose now to give some further account of most important investigations tending to the same result as that so earnestly desired by Lord Mayo, whose conclusions, it may be mentioned in passing, coincided substantially with those formed independently by the Duke of Argyll at home.

"It may be well to begin by reminding our readers that in October last (the 19th and 20th) we gave a pretty full account of what is known as the Fairlie system of railway working—a

system by which lines of the lightest construction and very narrow gauge may accomplish work hitherto deemed within the means only of lines of ponderous construction and broad gauge, and by which also the established lines of standard gauge may either partly diminish expenses, or, without additional cost, well-nigh double their carrying capacity. The characteristics of the system will appear in the sequel; for the present we proceed to state that Mr. Power, the Vice-chairman of the Poti and Tiflis Railway Company (a railway of 300 versts in the Caucasus), and Mr. Crawley, the contractor for its construction, were so struck with the merits of the Fairlie system, that they strongly recommended its adoption to the Russian Government, not only for the line prepared in the Caucasus, but also for all lines throughout that vast empire, where railways are of prime necessity, and where now, according to the new plan, five miles can be provided at a cost which was swallowed up in three miles, according to the old one. The recommendation carried the greater weight, inasmuch as the works of the Poti and Tiflis Railway were far advanced, and on a length of 15 versts the rails are actually laid down. The proposition, therefore, was that the Russian Government would find their advantage, even on these conditions, of changing the plans on which so much work had been expended, taking up the rails which have been laid down, and constructing the line on a gauge of 2 ft. 6 in., or exactly half the standard Russian gauge. The Minister for Public Works, Count Bobrinskoy, seized upon the idea. Mr. Fairlie went to St. Petersburg to explain his scheme in detail; and the result of all this is that an Imperial Commission has been sent over to this country to inspect the actual working of the system in various places, but chiefly on a wonderful little railway of 2 ft. gauge in Wales.

"The chief of the Commission is Count Alexis Bobrinskoy, cousin to the Minister of Public Works. He is accompanied by a considerable staff of engineers, foremost among whom may be mentioned Professor Saloff, of the Russian Imperial Institute; and Mr. Roehrberg, the manager of the most successful railway in Russia; and by personal friends, as Count Zamoyski and Count Alexander Berg, who take an interest in the question of railways. At the same time Mr. Fairlie offered to the Indian Government the opportunity of witnessing the experiments to be instituted for

the Russian Commissioners; and they, being themselves anxious for the means of improving and economizing their own railway system, at once resolved to take advantage of the offer. They appointed a Commission, consisting of Lieutenant-General Sir William Baker, R.E., and a member of the Council of India; Mr. Thornton, Secretary of the Public Works Department in the India Office; and Mr. Danvers, Government Director of Indian Railway Companies, to accompany the party. Captain Tyler also, the Government Inspector of Railways, who has already reported favourably on the Festiniog Railway of 2 ft. gauge, attended on behalf of the Board of Trade, and Mr. Pihl, Chief Engineer of Railways in Norway, was present on the part of the Norwegian Government. Besides these gentlemen, who went to witness the trials officially, others took an interest in the various proceedings in a private capacity; chief among them being the Duke of Sutherland and Count Béla Széchenyi, son of the Hungarian patriot of that name, who was well known in England some thirty years ago. The Duke took an especial interest in the inquiry, as he is not only a director of the North-Western Railway Company, but is himself the proprietor of a considerable length of railway on his Sutherlandshire estates.

"The party thus constituted started off on Thursday morning last in a special train of saloon carriages, and halting at Crewe to view the magnificent works of the North-Western Railway—the largest in Europe, with the exception of those at Creuzot in France—proceeded by Shrewsbury into Wales. At Welshpool they entered upon the Cambrian railway system, and, with the advantage of brilliant weather, were conducted by Mr. Elias through the very picturesque country, up hill and down dale and round curves of hill-sides, by which the line passes to Portmadoc. At Portmadoc is the terminus of the line known as the Festiniog Railway, of 2 ft. gauge (really 1 ft. 11½ in.), which was the principal subject of investigation.

"The Festiniog Railway, which is pronounced by no less an authority than Captain Tyler, the Inspector of Railways, to be the most instructive line in the three kingdoms, and which seems destined by its success to give a new impulse to railway engineering, is itself one of the oldest in existence. The Act for it was obtained in 1832, but in the first instance it was constructed only

for horse traction. It is a single line, $13\frac{1}{4}$ miles in length, with a branch of one mile connecting the slate quarries of Festiniog with the quays of Portmadoc. The terminus at Festiniog has 700 feet of elevation above that at Portmadoc, the average gradient being 1 in 92, which is enough to secure the descent of the trains on the return journey from Festiniog to Portmadoc by the impetus of gravitation—or, as the Welshman puts it, 'by its own impittence.' The line runs through a rude, rocky country, and has to adapt itself to an endless variety of curves along the contour of the hills, so that a train of any length has frequently to wriggle in serpentine fashion along two or three reverse curves, some of them sharp enough—the radius being $1\frac{3}{4}$ chain. On these curves the cant or super-elevation of the outer rails is never more than three inches. The line, in the old days when it was worked by horses, was originally laid with rails of 16 lbs. to the yard. When, about eight years ago, it was adapted to the locomotive, it was fitted with rails of 30 lbs. to the yard, most of which have been in use ever since. These, however, were found too light for the work, and are now being replaced by double-headed rails of $48\frac{1}{2}$ lbs. to the yard. The wheels of the carriages being less that 2 ft. apart, it is found convenient to arrange most of those for passengers after the fashion of an Irish car, with footboard overhanging the wheels. In this way the carriages are so low hung, and even carriages of the ordinary build are so near the ground in consequence of the small diameter of the wheels, that the expense of platforms at the stations is avoided. The whole expense of constructing and reconstructing the line, including tunnels, one of them 730 yards in length, with branch lines to the slate company's inclined planes and the quays at Portmadoc—in all 14 miles, has been 75,000*l.*, or at the rate of 5378*l.* a mile. The value of the rolling stock on the line is 28,000*l.*, or at the rate of 2000*l.* a mile. And now comes the most important point of all, which is that the original capital of the Company is 36,185*l.*, and that all the extra money which has been laid out upon the line has been taken from revenue. In this sense, therefore, as the net revenue of the company is 10,622*l.*, it appears that the line yields a dividend of $29\frac{1}{2}$ per cent. on the original capital. A sum of 50,000*l.*, however, paid out of revenue for improvements and reconstructions, has been capitalized, making the total capital 86,185*l.* In this sense the net revenue of the line

yields a dividend of $12\frac{1}{2}$ per cent. Whichever way the fact is to be stated, it is a most remarkable one, and must fill many a shareholder's heart with envy.

"The chief cause of this wonderful result is the narrowness of the gauge, which has enabled the Festiniog Company to economize in many ways. Thus, for example, the trucks for goods or minerals, even when fully loaded, have less of dead weight on a narrow than on a broad gauge. The best wagons on the standard gauge of 4 ft. $8\frac{1}{2}$ in. are reckoned to weigh about 7 cwt., and to carry $12\frac{1}{2}$ cwt. of pig iron or coal for every foot of their length, the dead weight being in the proportion of 56 to 100 of the *maximum* paying load, or 36 per cent. of the entire load. On the other hand, the wagon for a 3 ft. gauge is calculated to weigh $2\frac{1}{2}$ cwt., and to carry 8 cwt. for every foot of its length, the dead weight in this case being a very little over the proportion of 31 to 100 of the *maximum* paying load, and under 24 per cent. of the entire load. But there is still another point of view from which it can be shown that the wagons for goods and minerals on a line of narrow gauge are not so disproportionate in weight to the weight carried as they are on the broad gauge. In goods traffic it is well known that the dead weight of a train is enormous—something like 70 or 80 per cent. of the total weight hauled. If goods are to be delivered on a long line of railway, they are in this country arranged in many more wagons than are necessary to hold them, because a goods wagon cannot, like a passenger carriage, unload itself, and the train cannot wait till the unloading at a particular station is finished. It has to pass on, leaving the wagon of goods for that station behind; and it is more than probable that for this purpose the wagon has been but half or a quarter loaded. This becomes serious when wagons that weigh several tons carry but a fraction, often a small fraction, of their own weight. Such a source of expense disappears to a large extent on a narrow gauge line, where the wagons are comparatively small, and it is but one example of the saving which may be effected in the working of such a line, in addition to the saving of cost of construction in the first instance.

"This remark would hold good of the narrow gauge in itself and worked according to the ordinary system; but it is in the working of the Fairlie system that the greatest saving of all is effected,

and it is mainly, indeed almost entirely, in consideration of the economy, the increased power, and the diminished wear and tear which this system implies that a much narrower gauge than that now in general use has begun to find favour in the eyes of practical men. It was long before the Festiniog Railway Company could get an engineering firm to undertake to build a locomotive for a line of such steep gradients, combined with sharp curves, which they could guarantee. At last Messrs. George England and Co. undertook the task, and supplied engines which worked with perfect success, and then people began to believe in a railway of narrow gauge. One of Mr. Fairlie's engines has now been built for the line—it is called the 'Little Wonder,' as the other engines which have preceded it have been called the 'Welsh Pony,' the 'Little Giant,' as well as by other diminutive names—and the result has so surpassed expectation in the power it exerts, in its gentleness of action, in its economy of fuel, in its saving of the rails, and in its adaptation to troublesome curves and gradients, that for the first time practical men have discovered that a gauge of 2 ft. 6 in., or of 3 ft. at the very utmost, is enough for the heaviest traffic. It is no secret that two engineers of eminence, Mr. Fowler and Mr. Fairlie, have pronounced a 3 ft. gauge to be ample for all the requirements of India, and there were men of position in the party which went down to Wales, men with characters to lose, who made what seems to us the hazardous statement that on a gauge of even 2 ft. 6 in. they would undertake, with the Fairlie engine, to work the heaviest traffic in the world—that of the London and North-Western Railway. Be that as it may, it must be strange for those who can remember the battle of the gauges to find that what was then known as the narrow gauge is now in its turn attacked as being much too broad, and is even described in the terms which have been applied to more than one scheme of the Brunels as a gigantic folly. Our 4 ft. 8½ in. gauge is now established in so many countries—it is used not only in Great Britain, but also in France, Belgium, Switzerland, Italy, Austria, Prussia, Denmark, Egypt, the Cape of Good Hope, Australia, the United States, and Central America—that we seem to think of it as a standard of perfection. In some countries there will be found a still broader gauge—as in England itself, in Ireland, in the United States, in Canada, in Australia, in India,

in South America, in Portugal, in Spain, in Russia; but in very few will a narrower gauge be found. In England we have 14 miles on a 2 ft. gauge, and a few more on a slightly broader gauge; in Belgium there is a 3 ft. 8 in. gauge; in France, a 3 ft. 4 in. gauge; in India may be found a 4 ft. gauge; and in Norway and Sweden one of 3 ft. 6 in.; in the Mont Cenis Railway there is a 3 ft. 7½ in. gauge; and in Queensland one of 3 ft: 6 in.; and now we have opinion tending towards a gauge of 2 ft. 6 in., or of 3 ft., as the standard for the future.

"It is easy to determine on light railways of narrow gauge, and to construct them. The difficulty is to work them, and to work them in such a manner that their capacity and their economy shall bear comparison with railways of larger design and more elaborate construction. Hitherto railways of light construction and narrow gauge—that is, narrower than 4 ft. 8½ in.—have been in little favour, because of the limited power and destructive effects of the locomotive. Take, for example, the oscillation. This is very destructive on the standard gauge; it is, indeed, the chief cause of destruction to the permanent way—a fearful item of expense. But it is still worse on a narrow gauge, and necessitates diminished speed on battered rails. Therefore, practically, a narrow gauge was but of limited application to ordinary traffic until a locomotive, such as that of Mr. Fairlie, could be invented, free, or nearly free, from oscillation. And again, since a narrow gauge generally implies lightness of constrnction, and since lightness of construction implies sometimes roughness of workmanship, and nearly always such an adaptation of the railway to the surface of the country that it must dispense to a great extent with cuttings, viaducts, and other works, and must be ready to accept to the fullest extent possible a line of sharp curves and heavy gradients, it was necessary to devise a locomotive for it capable of good and safe speed on these conditions; and there was none such of sufficient note in existence until the double bogie engine of Mr. Fairlie was produced, which combined great size and power with freedom from oscillation and with a short wheel base that could be worked round curves of 60 ft. radius and even less.

"We must reserve for a day or two a full description of the performances of Mr. Fairlie's engines in Wales, because it is desirable to give the results of all the experiments, with their

success and their failure, together. The last of the experiments is made to-day, and we shall state all when we know all; but in the meantime we cannot be wrong in saying that there was an absolute unanimity of opinion among all those who witnessed the working of that narrow gauge railway at Festiniog that the standard gauge of 4 ft. $8\frac{1}{2}$ in. is far beyond all ordinary requirements. There may be some difference of opinion as to the precise gauge which is best. Mr. Spooner, the engineer of the Festiniog Railway, strongly advocated a gauge of 2 ft. 6 in., and he was supported in this view by practical men of great experience; others seem to hold that a gauge of 3 ft., giving greater freedom of space, would be the best, but all appeared to be convinced that a gauge much narrower than that now in general use is capable of work which is at present little imagined in the railway world. If this view be correct, it involves some most important results. Thus, let us take an ordinary line costing 15,000*l.* a mile, and compare it with one of narrow gauge worked in the new system, with power of carrying equal paying loads, and costing, as we have already indicated, three-fifths of the price of the other—namely, 9,000*l.* With a traffic return of 20*l.* every week for every mile, and deducting 50 per cent. for working expenses, the one railway would yield a dividend of about $3\frac{1}{2}$ per cent., while the other would yield very nearly 6 per cent.; and this calculation makes no allowance for the more economical working of the narrow gauge, which is one of the main features of the system. If such a result be possible it implies for public lines not a little encouragement to carry the railway system into every nook and corner of the kingdom where a moderate traffic may be obtained; and for Government lines the reduction of tariff to the lowest point.

"There seemed to be a unanimity of opinion also as to the success of Mr. Fairlie's engine adapted to the narrow gauge, and also on the broad gauge; but it remains to be seen, from the reports which will be furnished to the various Governments, how far this unanimity extends. That the engine did some extraordinary work is clear, as we shall have to show in a future article; but whether it is or is not to be recommended for adoption as a means of making the narrow gauge available to the utmost is a point on which we have no information."

No. II.

"The object of the experiments on the Welsh railways was to ascertain whether or not the 'Fairlie' engine increased the carrying capacity of a railway or diminished the cost of working it. With this view two engines were put on their trial—one, the 'Little Wonder,' on the Festiniog Railway, of 2 ft. gauge, in North Wales; the other, the 'Progress,' on the ordinary gauge of 4·8½, in South Wales.

"The 'Little Wonder' is an eight-wheeled double bogie engine of four cylinders $8\frac{3}{16}$ in. in diameter, with a stroke of 13 in. The diameter of its wheels is 2 ft. 4 in.; its average steam pressure is 150 lbs.; its weight is 19½ tons; its total length is 27 ft.; its total wheel base is 19 ft., and the wheel base of each bogie, which practically has alone to be considered, is 5 ft. This engine was first of all made to carry from Portmadoc to Festiniog a train made up of 90 slate wagons, weighing 57½ tons; 7 passenger carriages and vans, weighing 13½ tons; and 57 passengers, weighing 4 tons—in all, 75 tons. Add to this its own weight, and we have a total load of 94½ tons. The weight, it will be seen, was considerable, if we take into account the size of the engine, the narrowness of the gauge, the steepness of the gradients, and the sharpness and multitude of the curves. But the chief point of interest in this experiment had reference to the length of the train, which was 854 ft.—nearly the sixth part of a mile. A train of such a length on such a line had to run often upon two or three reverse curves, some of them with a radius as short as 1¾ chain, and it curled and doubled upon itself as it wound among the Welsh hills, so that the passengers in the front carriages could, sitting in their seats, make signals to the passengers in the hindmost ones. The engine, being in full gear, took this very long train up the hill and in and out among the curves at an average speed of 14½ miles an hour, and at a *maximum* speed of 26½ miles. Let us here add by way of parenthesis, in order not to refer to it again, that some days afterwards a similar train of 140 empty and seven loaded wagons, weighing in all 101 tons, and measuring in length 1323 ft.—*that is, a quarter of a mile*—a train so long, in fact, that there were parts of the road on which it had to run on no less than five reverse curves—was by the same engine hauled

up the hills at an average speed of $12\frac{1}{2}$ miles, and a *maximum* of $16\frac{1}{2}$. Now, what was the result observed in wriggling along these curves? It was generally observed (we now quote almost *verbatim* from the protocol signed by the chief witnesses), that even on curves of $1\frac{3}{4}$ chain radius, and at *maximum* speed, there was very little perceptible oscillation or movement on the engine or in the carriages, and by no means such as is felt on comparatively easy curves on ordinary railways. Nor must this remarkable point be forgotten—a fact almost incredible, but yet certified by competent witnesses—*that the oscillation diminished as the speed increased.* The speed, let it be added, is naturally less on a narrow gauge than on a broad one. Captain Tyler, the Government Inspector of Railways, was at first so doubtful of the safety of a high speed on a railway of such narrow gauge and such wild curves as that of Festiniog, that he insisted on limiting the Company to a *maximum* speed of 12 miles an hour. Since then, however, his doubts have been so completely dispersed that he has removed all restriction as to the rate of speed; and as a matter of fact the 'Little Wonder,' when necessary, works up to 30 and 35 miles an hour.

"Next day the oscillation of the 'Little Wonder' was put to a further test, and compared with that of the other engines—the 'Welsh Pony' and the 'Mountaineer'—which are of the ordinary type. In this series of experiments the speed was confined to 10 or 12 miles an hour on a comparatively level line, the gradient being only 1 in 1200; and the line was laid with rails weighing only 30 lbs. to the yard, and not fished at the joints. On the 'Welsh Pony' and the 'Mountaineer,' tank engines of the ordinary type, weighing the one 10 and the other 8 tons, it was found that there was a strong vertical oscillation and a lateral oscillation not so strong. On the 'Little Wonder,' the double bogie engine weighing $19\frac{1}{2}$ tons, it was found that when riding on the foot-plates there was no oscillation whatever, vertical or lateral, perceptible—only 'a smooth floating movement'; and that when riding on the bogie frames there was felt a slight lateral oscillation, though less than on the other engines. It is added that the oscillation of the 'Fairlie' engine being confined to the bogie, the influence of impact on the rails from the flanges of the wheels was far less than in the case of the 'Welsh Pony' and the

'Mountaineer,' the whole weight of these engines being in the course of their oscillations brought to bear upon the rails.

"Next followed some rather tedious but very interesting trials as to the comparative powers of the two classes of engine. The 'Welsh Pony' was selected to represent the common type of engine. It is a four-wheeled locomotive, weighing 10 tons, with cylinders $8\frac{1}{8}$ in. diameter, having a stroke of 12 in., and with wheels 2 ft. in diameter. It was in the first instance tacked on to a load of 50 slate wagons full of slate, weighing $123\frac{1}{2}$ tons. To this add $3\frac{1}{2}$ tons for passengers and 10 tons for its own weight, and we get at the entire load of 137 tons. With this the 'Welsh Pony' started from Portmadoc, and, running along the comparative level (1 in 1200) of the Traethmawr embankment, stopped on a gradient of 1 in 85, unable to proceed farther, with 160 lbs. to the square inch of steam pressure. Hereupon half the number of wagons was removed, and the load (including passengers and the engine itself) was consequently reduced to 72 tons 17 cwt. With this load it was found that the 'Welsh Pony' could mount the gradient of 1 in 85 easily enough. Being successful with 25 wagons, the question arose could it manage more? It was then tried with 30 wagons, but on the gradient of 1 in 85 it was found that it could not start, though, since the engine-wheels did not revolve, there was no lack of adhesion. Then again the load was reduced to 26 wagons, weighing (with passengers and engine) 73 tons 16 cwt., and it was found that this was the limit of the 'Welsh Pony's' power. It started with such a load on the gradient of 1 in 85, and carried it as far as was necessary at the rate of five miles an hour—the average pressure being 150 lbs. to the square inch. If the 'Welsh Pony' could carry nearly 74 tons up such a gradient, and with this load also start on it, what could the Fairlie engine, the 'Little Wonder,' do? It was supposed that it ought to pull double. If the 'Welsh Pony' could, on a gradient of 1 in 85, manage 26 wagons full of slate, weighing with all else 74 tons, surely the 'Little Wonder' could manage 52. Mr. Fairlie said he was quite prepared for this; he would stake the credit of his little engine on its power to carry such a load; and to show that he could be generous, he even added three wagons to the load; he thought his engine could manage 55 wagons. However, as the 'Welsh Pony' had first of

all been tried with an excessive load, it was but fair that the 'Little Wonder' should be similarly tried. A train was prepared of 72 loaded wagons of slate, weighing 138 tons 17 cwt., with empty ones weighing 43 tons 10 cwt.; and when you add to this 56 passengers, weighing 4 tons, and the weight of the engine itself, 19½ tons, you have a total load of 206 tons. With this load the 'Little Wonder' started from Portmadoc (steam pressure 165 lbs.), and passing along the level embankment, went up the gradient of 1 in 85 with perfect ease, and to the astonishment of all the visitors, who crowded round Mr. Fairlie and shook him heartily by the hand on such a triumph. His engine was warranted to do double the work of ordinary engines, and on trial it was found equal to treble the work. But then arose the question—The 'Little Wonder' has pulled such a load up the gradient of 1 in 85, having had a good start on the level embankment; can it start with this load on the gradient itself? It was, perhaps, scarcely fair to make the trial, inasmuch as the day was wearing late, and the engine-driver had, through a misapprehension, let the fire run low. Still the trial was made, and with perfect success. There is this further, however, to be added, that whereas the shorter trains were standing when they started, or attempted to start, partly on a curve of 4½ chains radius, partly on a straight line, the train of the 'Little Wonder,' being much longer (it was 648 ft.), stood partly on the curve of 4½ chains radius and partly on a reverse curve of a little wider sweep, which, of course, means an increased resistance, and might be resolved into an increase of gradient. Also let us add here, to complete the statement, what really happened four or five days afterwards, that whereas these experiments last described were intended to test the extreme power of the engines, other experiments followed to show what the 'Little Wonder' could do, not merely in a short run, but in its ordinary daily work between Portmadoc and Festiniog. It took, for example, a train 407 ft. long, and loaded to 141½ tons, from Portmadoc to Festiniog, at a *maximum* speed of 15 miles an hour, and an average one of 11¼. The usual practical load, however, of the 'Little Wonder,' upon the average gradient of 1 in 92, is from 90 to 100 tons (exclusive of engine), at from 12 to 15 miles an hour. On a level it is calculated that its power is equal to the carriage of 450 tons, at a speed of 14 miles an hour.

"After the experiments on the Festiniog Railway, the exploring party met together in council, under the presidency of the Duke of Sutherland, to hear Mr. Spooner read a paper on the wonderful little line of which he is the engineer, and to compare with each other their notes and impressions. Mr. Spooner gave ample information on every detail connected with his railway, which in the year ending June, 1869, had a mineral traffic of 118,132 tons, a goods traffic of 18,600 tons, and a passenger traffic of 97,000 persons, but no night traffic and no Sunday trains. His paper will, no doubt, be published, and those who may be interested in the subject will find in it all the statistics of which we have given the cream. We only state here that he wound up his remarks by saying that he does not recommend for light railways a gauge so narrow as 2 ft. The gauge he recommends is one of 2 ft. 6 in. The large amount of traffic which can be done with ease on lines of this limit is, he said, really surprising, and with the Fairlie engine it is quite equal to that which can be earned on a 4 ft. 8½ in. gauge. Hereupon the discussion became general, but we can refer to only a few of the opinions which were expressed. The Duke of Sutherland said he wished he had known more of the Festiniog Railway six years ago. 'I have expended,' said his Grace, 'about 200,000*l.* in promoting and making railways in the north. Had these lines been constructed on the narrow gauge, and had they in consequence cost only two-thirds of the sum that had been expended on them, I should have obtained a direct return on this large sum which I have laid out for the benefit of my estates and of the people in those remote districts. As it is, I shall suffer considerable loss.' Then Mr. Crawley insisted, in a vigorous argument, on the perfect sufficiency of a 2 ft. 6 in. gauge, if worked on the Fairlie system, for the heaviest traffic, and on the folly, if this were sufficient, of adding another inch to the gauge. The argument may be sound as regards heaviness of traffic, but as other considerations besides the weight to be carried have to be taken into account, as, for example, the comfort of passengers, and the bulk of goods, say in a cotton country, it is natural that there should be some difference of opinion as to the precise narrow gauge which is best. It will be seen that Mr. Fowler and Mr. Fairlie have both recommended a 3 ft. gauge for India; and it is not at all unlikely that this gauge may ultimately be adopted in Russia."

Advantages Gained by Construction of Narrow Gauge Railways.

It will appear there should be—

First. A defined mode for construction of line.

Second. A defined mode for construction of rolling stock.

Third. A defined mode for application of motive power.

Fourth. It will appear that the proper application of these three will embrace the desired combination in railway construction.

To effect such object, has to be considered a system of one gauge for railways, suitable for any country and every variety of ground, either mountainous, ordinary, or undulating. The gauge should be fixed as narrow as practically possible, for the reason that the narrower the gauge, the lighter the section of works which can with facility be secured by the introduction of sharper radii curves, besides thereby reducing flange and drag friction to a minimum on all curves, and embracing the most important feature of largely reduced cost in railway construction. The gauge must not be too narrow to ensure sufficient stability of the rolling stock on way, together with ample speed for all practical purposes.

Secondly. The rolling stock to be so constructed as to possess the advantage of minimum wear and tear of permanent way and rolling stock, and to have ample floor area for all practical purposes.

Thirdly. The motive power to be so arranged as to possess advantage of minimum wear and tear of engine and of permanent way, and possessing ample power for all practical purposes; nor should there be a preponderating weight on each driving wheel of locomotive engine or of rolling stock on permanent way, than will fairly wear out the rails without crushing or disintegrating the metal, and for such purpose to have no greater vertical weight of any one wheel on rail than three tons.

It may be true that the gauge for railways of one country is not applicable for another, but I think it must be admitted that any gauge which is sufficient, must be one universally applicable, or that may in different countries, or under peculiar circumstances, require only some small modification. It is certain that railways should be constructed so as to carry anything or everything that can reasonably be demanded by the public.

Now, if a system of narrow gauge railways is to be resorted to for general use, there must be some very tangible reasons given for its introduction. I know they will be resorted to because

they can be made cheaper; that they can be made to perform as much traffic as the larger lines; that they can be maintained at a less cost; but, on the other hand, that locomotive engines with driving wheels of proportionately reduced diameters cannot be made to travel at the higher velocities of the ordinary lines.

It is rarely that ground throughout the route of a line of railway can be found so favourable that the *same* radii of curves would be selected for *both* gauges, but the advantages offered by the small gauge would be taken, namely, that of following the contour of the country by hugging the hill-sides, thus avoiding heavy cuttings, viaducts, tunnels, &c., and reducing proportionately the first cost to formation level, and also of the permanent way.

Assuming that a railway on 2 ft. 6 in. or 2 ft. 9 in.* gauge and 4 ft. $8\frac{1}{2}$ in. gauge of 50 miles in length, in junction with a main line of the standard gauge, was projected through an ordinary country having the *same* longitudinal section and the *same* radii of curves for either line, the comparison of works and cost will be as per following diagrams and tables:—

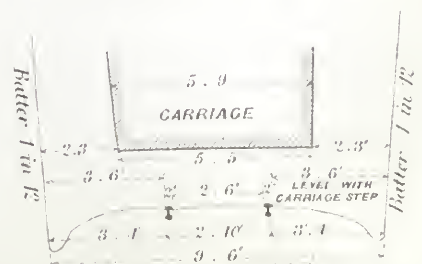
Comparative Estimate of Cost of Permanent Way per Mile for 2 ft. 6 in. and 4 ft. $8\frac{1}{2}$ in. Gauge Railway.

	t. c. q.		£ s. d.	£ s. d.
2 ft. 6 in. Gauge.				
Rails, 55 lbs. per lineal yard	86 8 2	at per ton	8 0 0	691 8 0
†440 pairs of fish-plates, 15 lbs. per pair	2 19 0	"	8 10 0	25 1 6
1760 fish-bolts and nuts, 100 lbs. per 100	0 15 3	"	15 0 0	11 16 3
3960 chairs, 19 lbs. each	33 0 2	"	8 0 0	268 12 0
7920 chair-pins, 28 lbs. per 100 pins ..	0 19 3	"	15 0 0	14 16 3
1980 sleepers, 5 ft. × 9 in. × $4\frac{1}{2}$ in. ..	..	each	0 1 8	165 0 0
3960 wooden keys	..	"	0 0 $1\frac{1}{2}$	24 15 0
Ballast, $1\frac{1}{4}$ cube yard per lineal yard	2200 cub. yds.	per cub. yd.	0 1 0	110 0 0
Platelayers' works	..	..	..	73 0 0
			£	1384 9 0
4 ft. $8\frac{1}{2}$ in. Gauge.				
Rail, 80 lbs. per lineal yard	125 14 1	at per ton	8 0 0	1005 14 0
†440 pairs of fish-plates, 28 lbs. each	5 10 0	"	8 10 0	46 15 0
1760 bolts and nuts, 125 lbs. per 100	0 18 1	"	15 0 0	13 13 9
3960 chairs, 26 lbs. each	45 19 1	"	8 0 0	367 14 0
7920 chair-pins, 40 lbs. per 100 pins ..	1 18 1	"	15 0 0	21 3 9
1980 sleepers, 9 ft. 6 in. × 5 in. × 10 in.	..	each	0 3 9	371 5 0
3960 wooden keys	..	"	0 0 $2\frac{1}{2}$	41 5 0
Ballast, 3 cube yards per lineal yard	3960 cub. yds.	per cub. yd.	0 1 0	198 0 0
Platelayers' works	..	..	..	88 0 0
			£	2153 10 6

* The introduction of *inside* cylinders for first-class powerful engines will necessitate a gauge of 2 ft. 9 in., and not 2 ft. 6 in., notwithstanding engines with inside cylinders can be made for 2 ft. 6 in. gauge, but in construction will be somewhat confined for space.

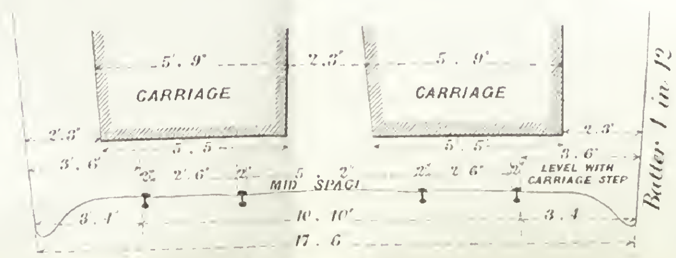
† The difference in cost of way will in reality be greater as the usual length of rail

Section of Single Line of Way for 2. 6" Gauge.



Minimum Width.

Section of Double Line of Way for 2. 6" Gauge.

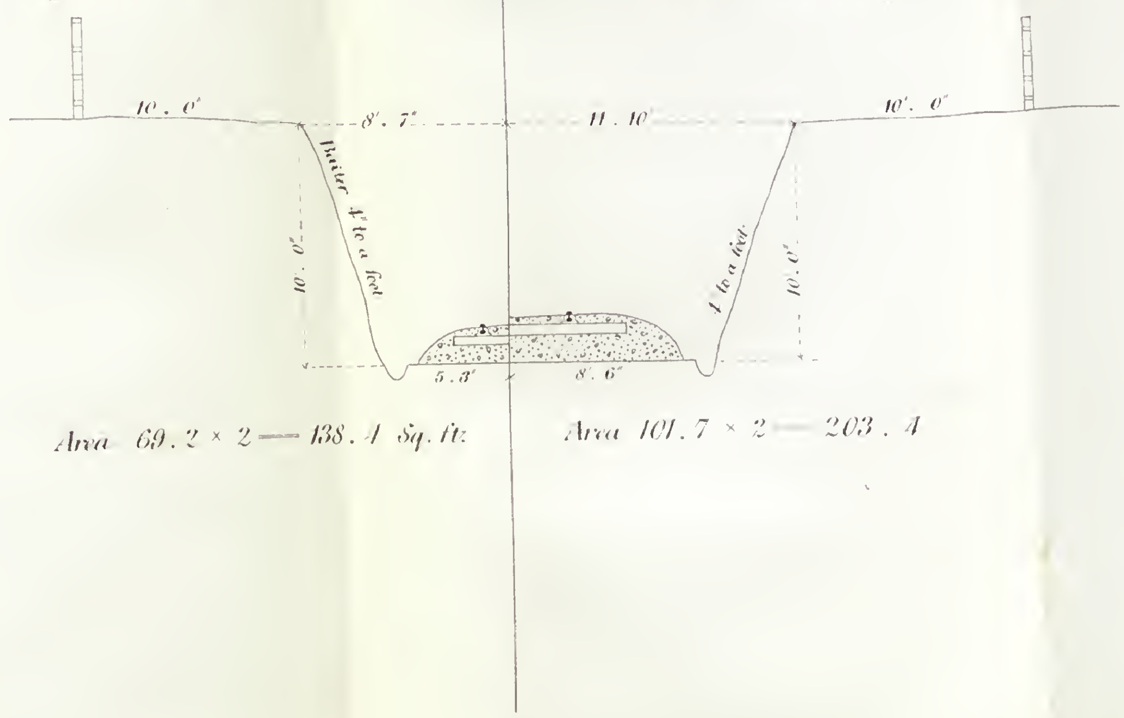


Minimum Width.

No. 1.

Half Section of Rock Cutting for Single Line of Way on 2'. 6" Gauge.

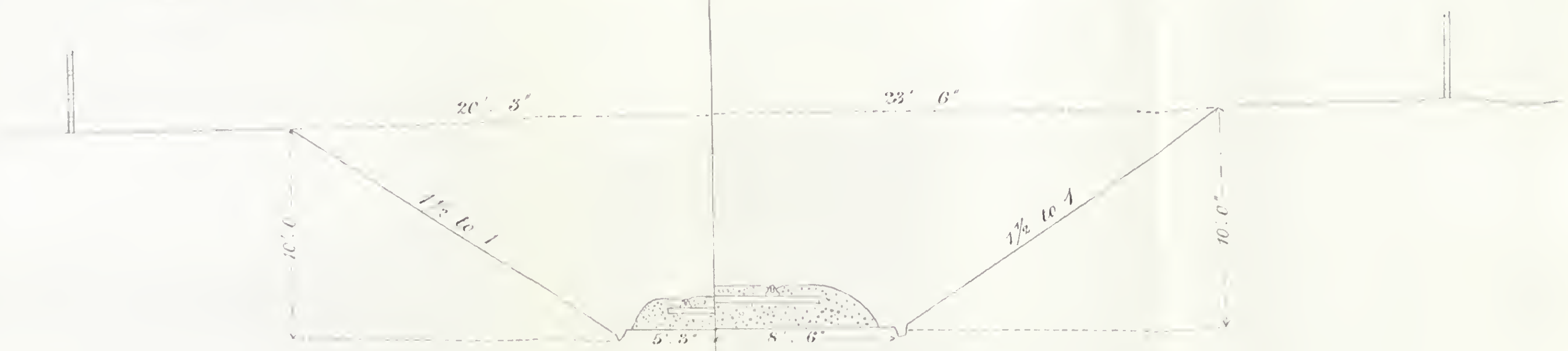
Half Section of Rock Cutting for Single Line of Way on 4'. 8½" Gauge.



No. 2

Half Section of Soil Cuttings for Single Line of Way on 2'. 6" Gauge

Half Section of Soil Cutting for Single Line of Way on 4' 8½ Gauge

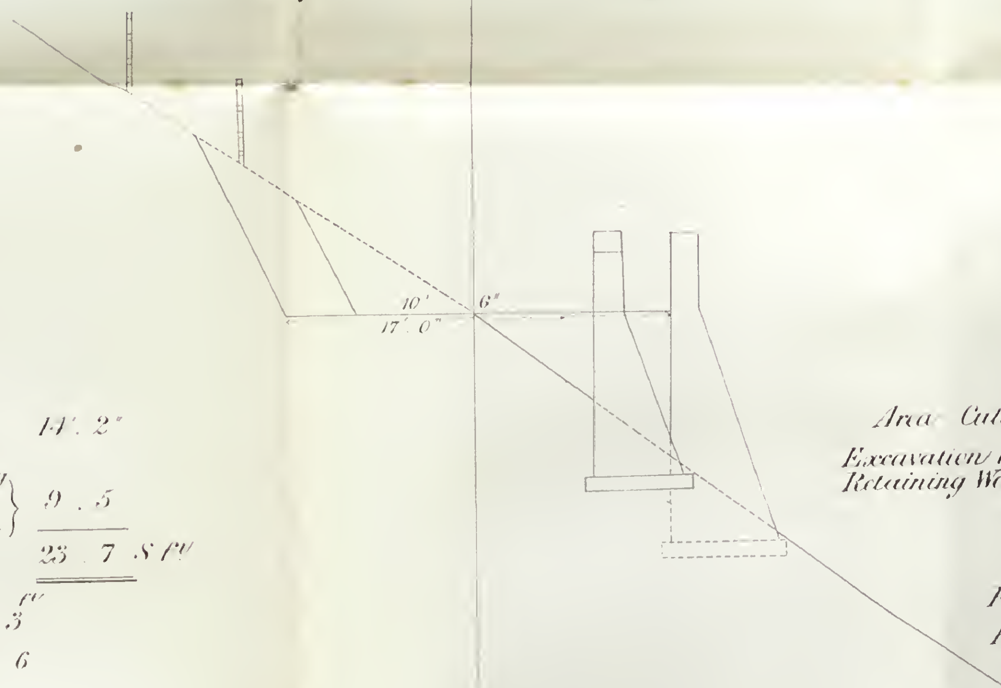


Area 127·5 × 2 255 Sq. feet

Area 160 × 2 320 . Sq. feet

No. 3.

Section of Side Cutting and Filling for Single Line of Way on 4'. 8½ 2'. 6" Gauge



Area Cutting 14'. 2"
Excavation for Ret.g Wall } 9 . 5
23 . 7 S. ft.

	s	ft
Embankment	9	3
Retaining Wall	29.	6

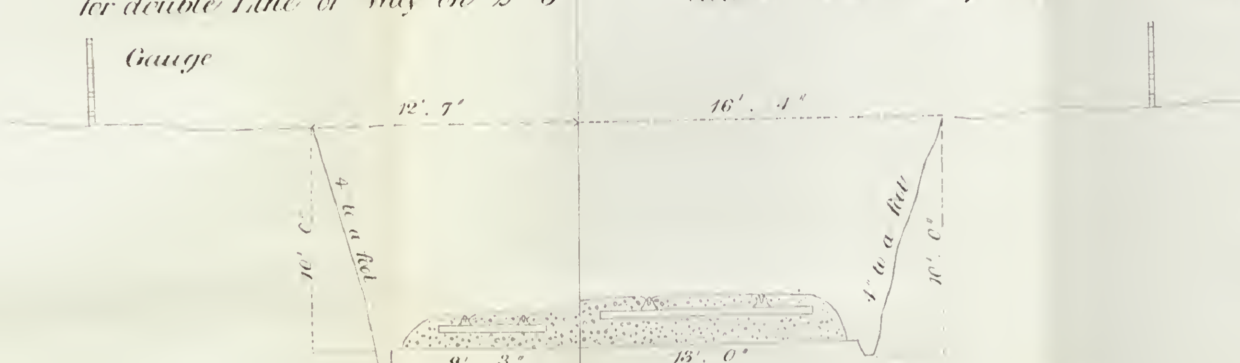
	s	ft
Area Cutting	38	7
Excavation for Retaining Wall }	14	0
	52	7 S. feet

Embankment 26 . 3
Retaining 43 . 9

No. 4

Half Section of Rock Cutting for double Line of Way on 2' 6" Gauge

Half Section of Rock Cutting for double Line of Way on 4' 8½ Gauge



Area 109. 2 × 2 218. 4 S. feet

Area 146 7" × 2" 293 4 S. feet

No. 5

Half Section of Soil Cutting for Double Line of Way on 2.6 Gauge

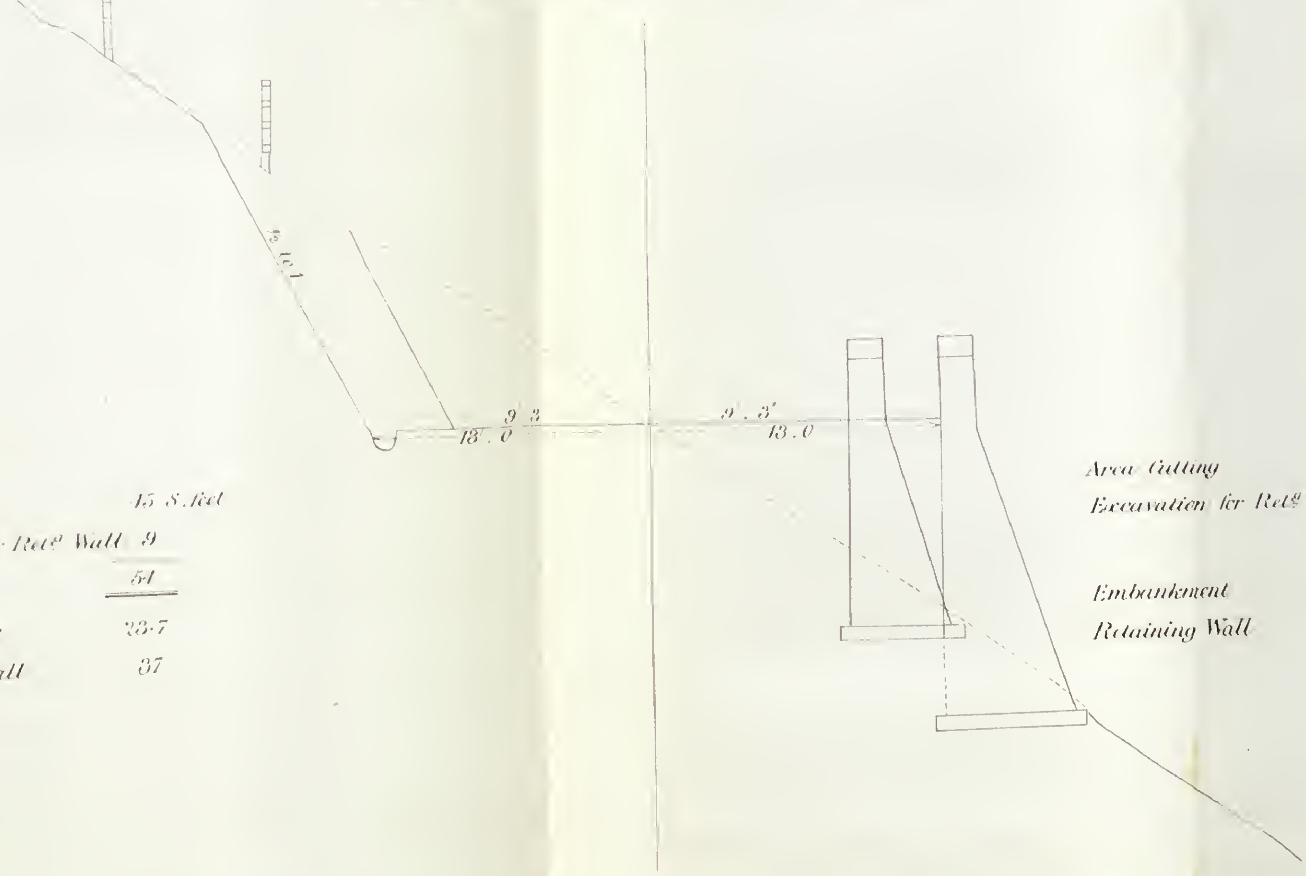
Half Section of Soil Cutting for Double Line of Way on 4.8½ Gauge

Area 167.5 × 2 = 335 S. feet

Area 205 × 2 = 410 S. feet

No. 6

Section of Side Cutting & filling for Double Line of Way on 2.6" and 4.8½ Gauge



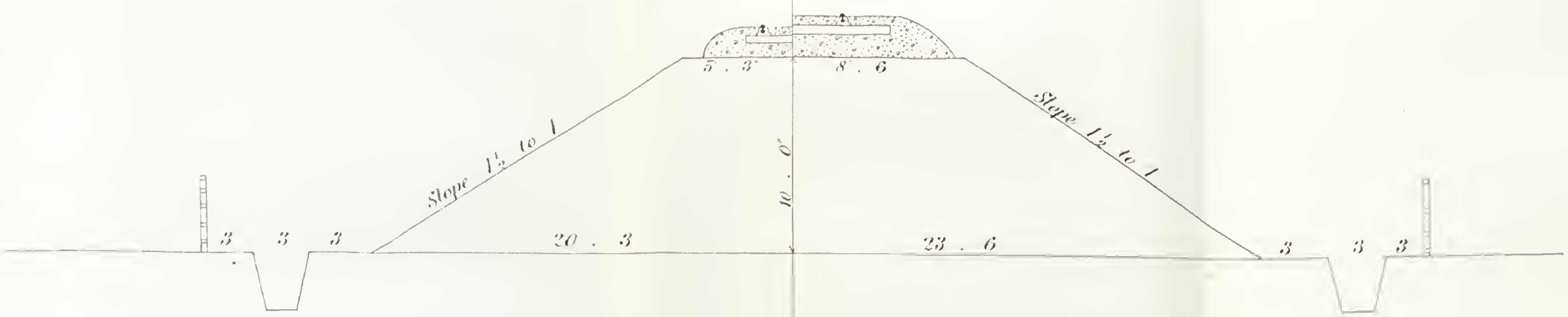
Area Cutting	45 S. feet
Excavation for Retg Wall	9
	54
Embankment	23·7
Retaining Wall	37

Area Cutting	95·3 . S. feet
Excavation for Retg Wall	12.7, S. feet
	108.0
Embankment	50.5 S. feet
Retaining Wall	51 S. feet

No. 7.

Half Section of Soil Filling for Single Line of Way on 2'. 6" Gauge

Half Section of Soil Filling for Single Line of Way on 4'. 8½" Gauge



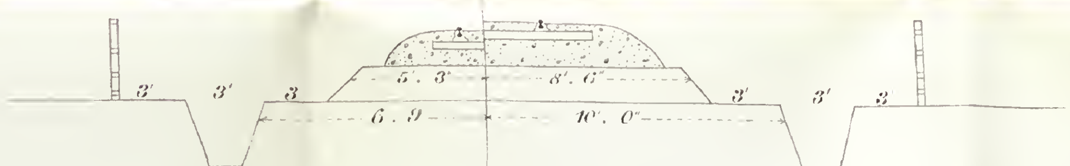
Area 127.5 × 2 — 255 S. feet.

Area 160 × 2 — 320 S. feet.

No. 8.

Half Section of Soil Filling for Single Line of Way on 2'. 6" Gauge.

Half Section of Soil Filling for Single Line of Way 4'. 8½" Gauge.



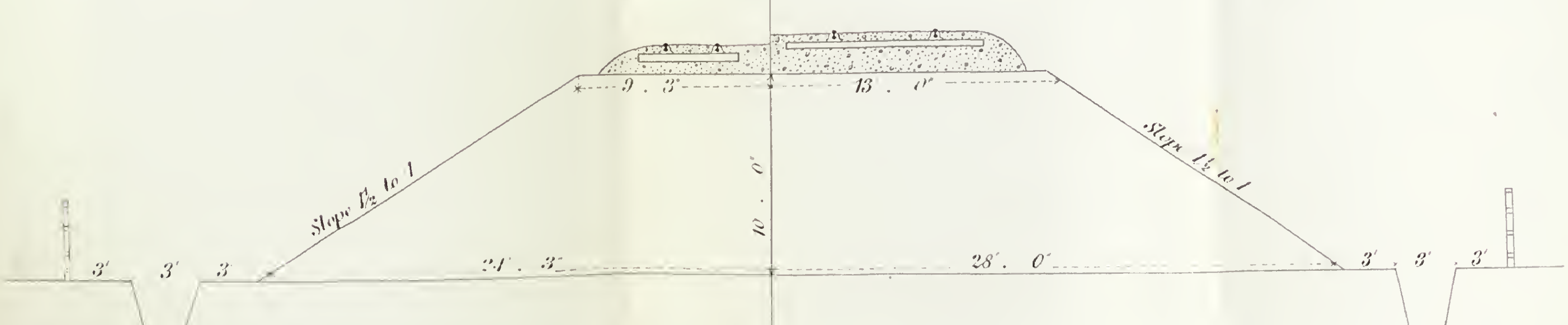
Area 9 × 2 — 18 S. feet

Area 13.9 × 2 — 27.8 S. feet

No. 9.

Half Section of Soil Filling for Double Line of Way on 2'. 6" Gauge.

Half Section of Soil Filling for Double Line of Way on 4'. 8½" Gauge.

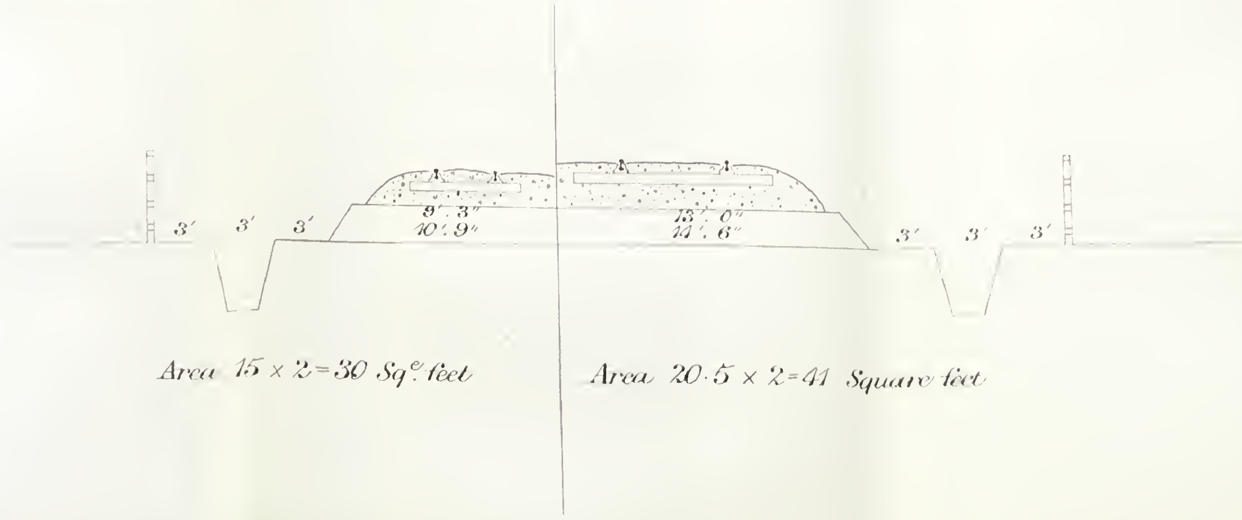


Area 167.5 × 2 = 335 S. feet

Area 205 × 2 — 410 S. feet

Nº 10.

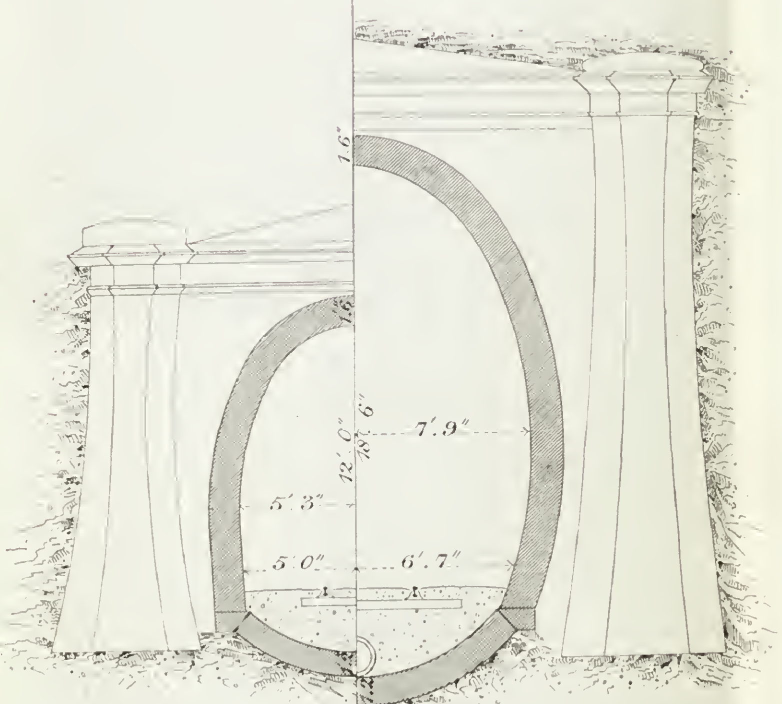
Half Section of Soil Embankment for Double line of Way on 2'.6" Gauge | *Half Section of Soil Embankment for Double line of Way on 4'.8½" Gauge.*



Area 15 × 2 = 30 Sq.e feet | Area 20·5 × 2 = 41 Square feet

Nº 11.

Half Section of Tunnel for Single line of Way on 2'.6" Gauge | *Half Section of Tunnel for Single line of Way on 4'.8½" Gauge*

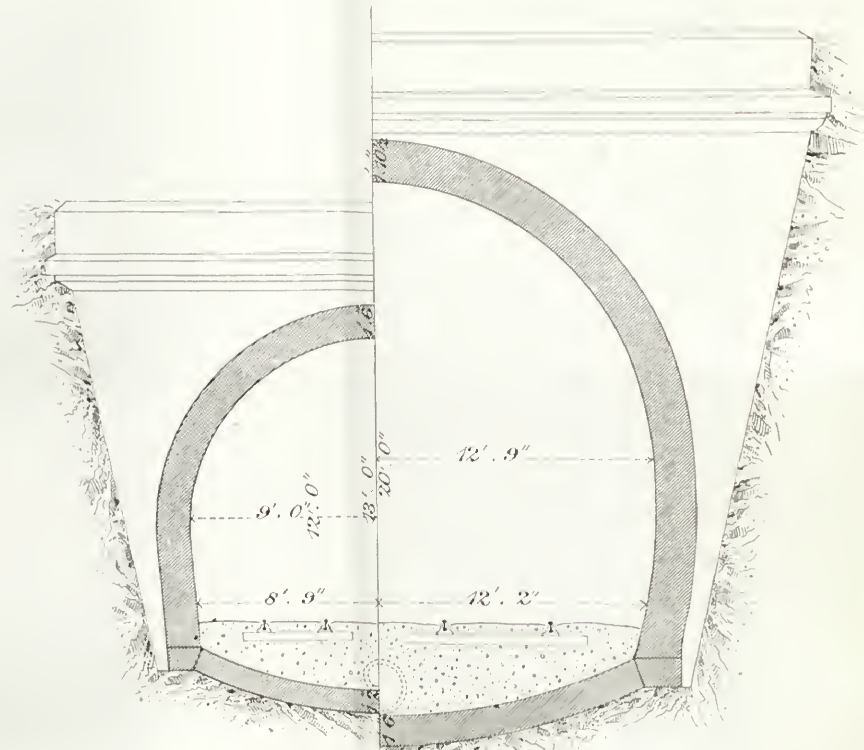


Area of Excavation 90 × 2 = 180 sq. ft.
" Brickwork 30 × 2 = 60 "
Area of Masonry at Entrance } 173 "

Area of Excavation 183 × 2 = 366 sq. ft.
" Brickwork 46·5 × 2 = 93 "
Area of Masonry at Entrance } 281 "

Nº 12.

Half Section of Tunnel for Double line of Way on 2'.6" Gauge | *Half Section of Tunnel for Double line of Way on 4'.8½" Gauge*



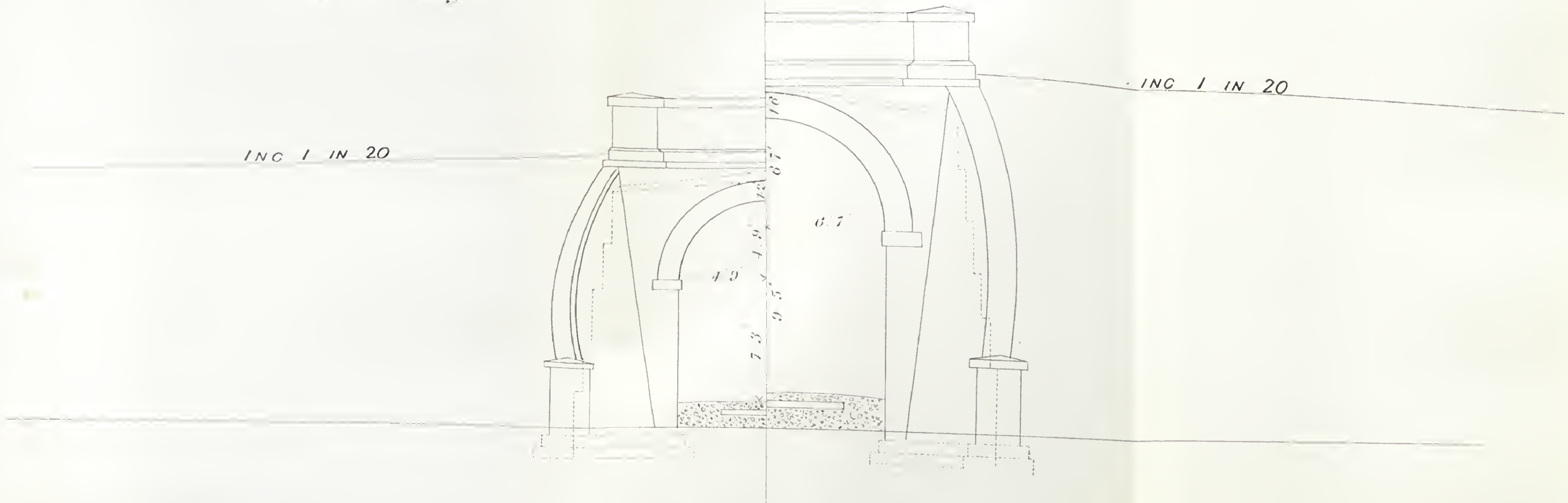
Area of Excavation 167 × 2 = 334 sq. ft.
" Brickwork 41 × 2 = 82 "
Area of Masonry at Entrance } 143 "

Area of Excavation 334 × 2 = 668 sq. ft.
" Brickwork 72·5 × 2 = 145 "
Area of Masonry at Entrance } 274 "

No. 13

Half Section of Over Bridge for Single Line of Way on 2.6″ Gauge.

Half Section of Over Bridge for Single line of Way on 4.8½ Gauge.



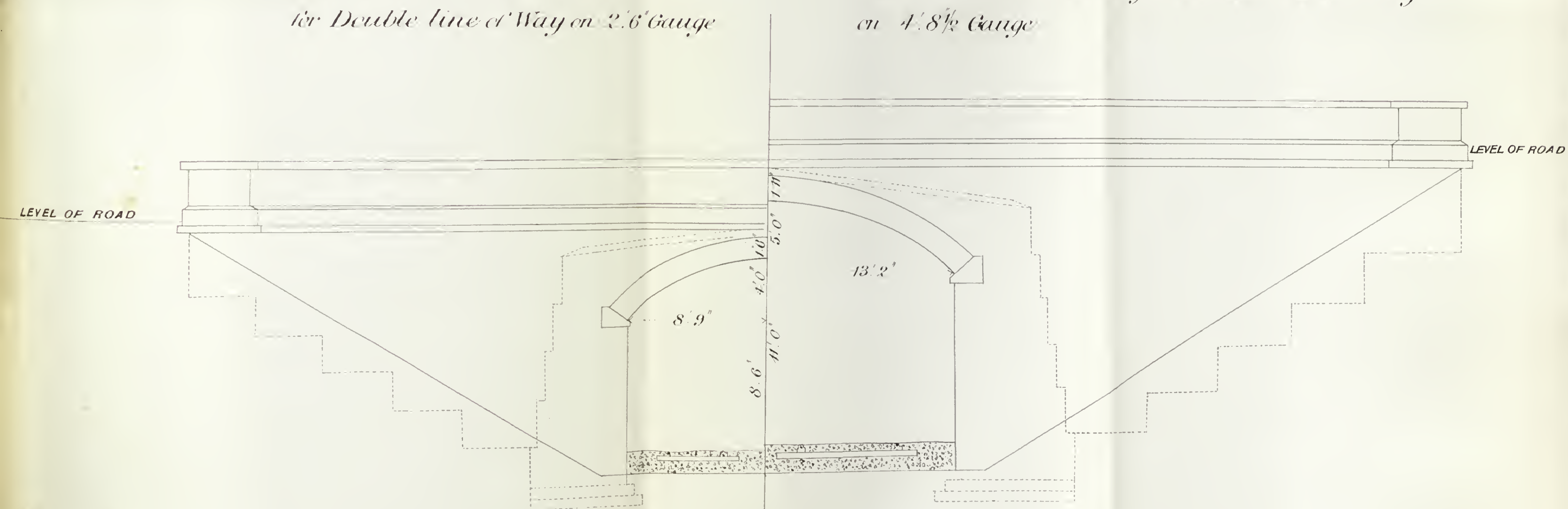
Area of	Parapet	38 × 2	—	76	S. Ft
"	Arch	9.5 × 2	—	19	" —
"	Abutment	74 × 2	—	148	" —
"	Wingwall	219 × 2	—	438	" —
"	Road Filling	4640 × 2	—	9280	—

Area of	Parapet	51 × 2	—	102	Sq. Ft
"	Arch	17.5 × 2	—	35	— " —
"	Abutment	108 × 2	—	216	— " —
"	Wingwall	393 × 2	—	786	— " —
"	Road Filling	7980 × 2	—	15960	— " —

No. 14

Half Section of Over Bridge for Double line of Way on 2.6″ Gauge

Half Section of Over Bridge for Double line of Way on 4′.8½ Gauge

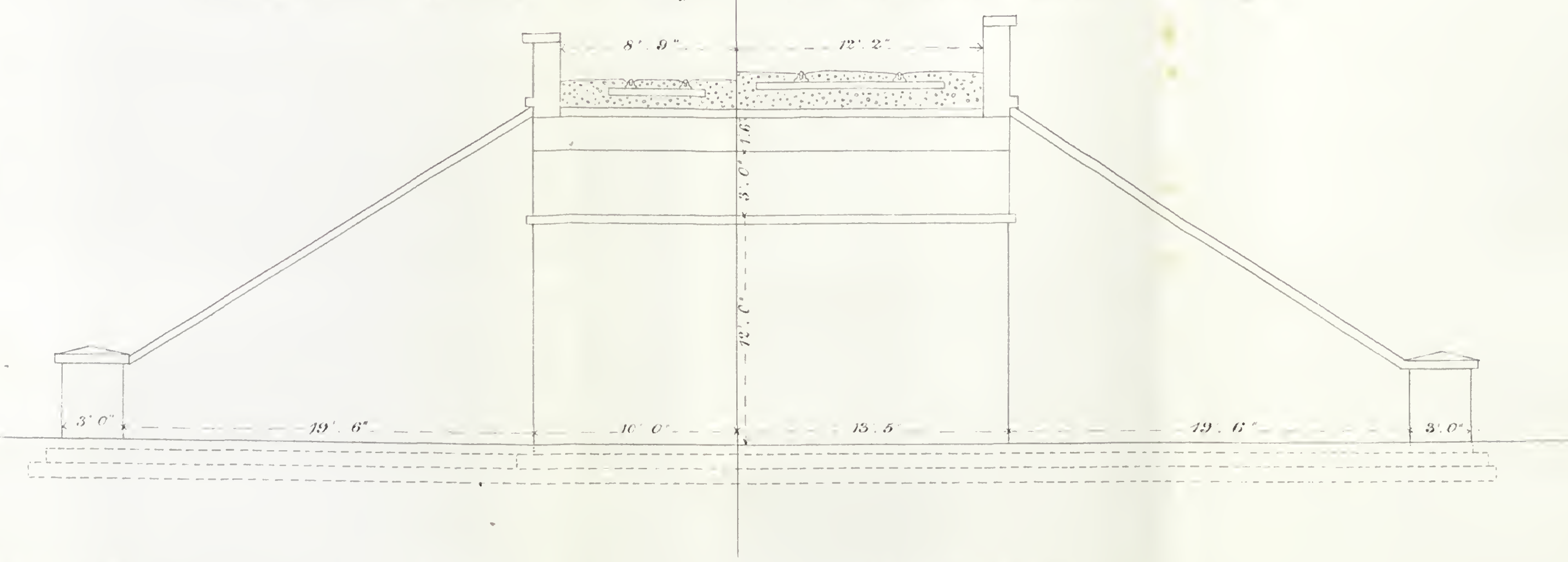


Area of	Parapet	157 × 2	—	314	S. Ft
"	Arch	16.5 × 2	—	33	" —
"	Abutment	85 × 2	—	170	" —
"	Wingwall	208 × 2	—	416	" —

Area of	Parapet	201 × 2	—	402
"	Arch	27 × 2	—	54
"	Abutment	33 × 2	—	246
"	Wingwall	346 × 2	—	692

No. 16

Half Section of Under Bridge for Double Line of Way on 2' 6" Gauge | *Half Section of Under Bridge for Double Line of Way on 4' 8½ Gauge*

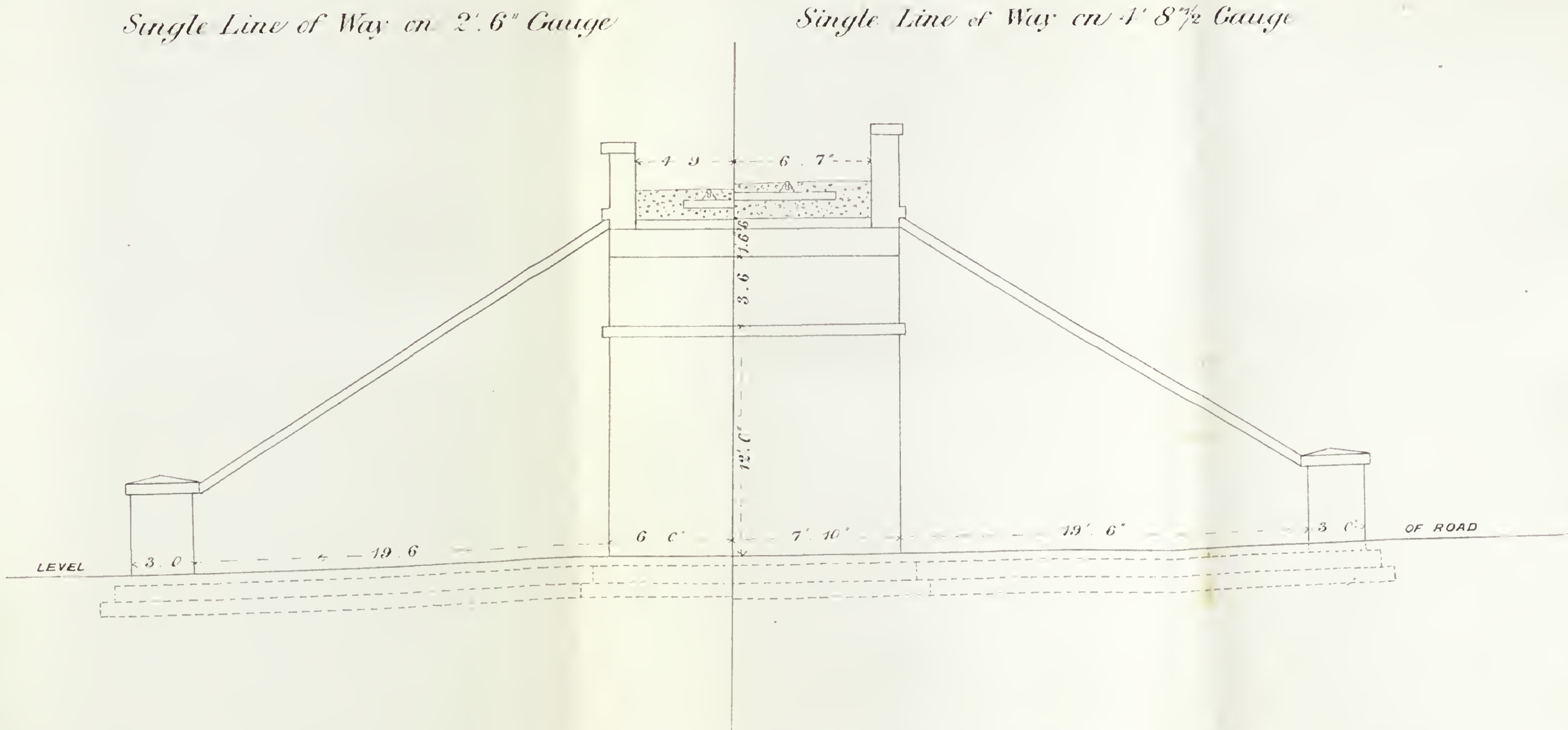


Area Arch	140	×	2	=	280
" Abutment	141	×	2	=	282
" Wing Wall & Newell	275	×	2	=	550
" Parapet	90	×	2	=	180

Area of Arch	188	×	2	=	376
" Abutment	199	×	2	=	382
" Wingwall & Newell	275	×	2	=	550
" Parapet	112	×	2	=	224

No. 15

Half Section of Under Bridge for Single Line of Way on 2'. 6" Gauge | *Half Section of Under Bridge for Single Line of Way on 4' 8½ Gauge*



Area Arch	84	×	2	=	168
" Abutment	83.5	×	2	=	167
" Wingwall & Newell	275	×	2	=	550
" Parapet	90	×	2	=	180

Area of Arch	110	×	2	=	220
" Abutment	112	×	2	=	224
" Wingwall & Newell	275	×	2	=	550
" Parapet	112	×	2	=	224

COMPARATIVE TABLE of WORKS on a 2 ft. 6 in. and 4 ft. 8½ in. GAUGE LINE, having the same LONGITUDINAL SECTION for each LINE.

Description.	Single Line of Way. Gauge, 2 ft. 6 in.	Gauge, 4 ft. 8½ in.	Proportion per Cent. of 2 ft. 6 in. to 4 ft. 8½ in. Gauge.	Mean Percentage of different Works of 2 ft. 6 in. to 4 ft. 8½ in. Gauge.	Double Line of Way. Gauge, 2 ft. 6 in.	Gauge, 4 ft. 8½ in.	Proportion per Cent. of 2 ft. 6 in. to 4 ft. 8½ in. Gauge.	Mean Percentage of different Works of 2 ft. 6 in. to 4 ft. 8½ in. Gauge.
	s. ft.	s. ft.			s. ft.	s. ft.		
Land	..	..	..	76	..	..	..	74
EARTHWORKS :—								
Rock cutting	138·4	203·4	68·04	64·20	218·4	293·4	74·43	68·70
Soil cutting	255·0	320·0	79·68		335·0	410·0	81·70	
Sideland cutting ..	23·7	52·7	44·99		54·0	108·0	50·00	
Embankment	255·0	320·0	79·68	60·21	335·0	410·0	81·70	65·37
Ditto from side trench	18·0	27·8	67·71		30·0	41·0	73·17	
Sideland filling ..	9·3	26·3	35·32		23·7	50·5	46·93	
Road filling	9280	15960	58·14		9740·0	16310·	59·71	
Retaining walls ..	29·6	43·9	67·42	67·42	37·0	51·0	72·54	72·54
TUNNELS :—								
Excavation	180	366	49·18	58·41	334	668	50·00	52·91
Lining	60	93	64·51		82	145	56·55	
Masonry at entrance	173	281	61·56		143	274	52·19	
BRIDGES :—								
(Over).								
Parapet	76	102	74·50	63·25	314	402	78·10	67·10
Arch	19	35	54·28		33	54	61·11	
Abutment	148	216	68·51		170	246	69·10	
Wing wall	438	786	55·73		416	692	60·11	
(Under).								
Parapet	180	224	80·35	82·81	180	224	80·35	82·15
Arch	168	220	76·36		280	376	74·46	
Abutment	167	224	74·55		282	382	73·82	
Wing wall	550	550	100·00		550	550	100·00	
PERMANENT WAY :—								
Double-headed rails, chairs, pins, fish-plates, bolts, sleepers, ballast, and platelaying, per mile	£1384	£2153	64·29	64·29	£2768	£4306	64·29	64·29
Fencing	same for both lines							
Signals	" "							
Telegraphs	" "							
Stations	" "		(except platforms)					

The aggregate mean proportion of the various works enumerated above, will show a gain in favour of a single line of way on

for a 4 ft. 8½ in. gauge is 21 ft., but the length of rail for a gauge of 2 ft. 6 in. should be 27 ft., or as 502 pairs of fish-plates is to 390, or a saving of 112 joints in each mile.

2 ft. 6 in. gauge of 33 per cent., and of a double line of way of 32 per cent.

The comparative difference in favour of a 2 ft. 9 in. over a 5 ft. 6 in. gauge, will be 35 per cent. single line, and 34 per cent. double line, with the *same* longitudinal section for both lines.

The reduction of 24 per cent. in land on lines in the vicinity of large towns, where property is so valuable, would amount to an important saving. Supposing that the Metropolitan Railway had been made on this system, the saving to shareholders in this item alone would have been enormous, besides lesser cost in earthworks, tunnels, retaining walls, &c., and compensation to adjoining properties,* at the same time accomplishing the traffic.†

No raised platforms at stations will be required for a 2 ft. 6 in. or 2 ft. 9 in. gauge. The raised platforms of 100 yards in length for 4 ft. 8½ in. gauge, will amount to 1000 cube yards of work for each station of fair ordinary traffic, which would be saved on the 2 ft. 6 in. or 2 ft. 9 in. gauge, besides the proportionate gain above shown in other works.

The absence of raised platforms also lessens the liability to accidents at stations.

The main sidings on the smaller gauge will require to be about one-fourth longer than on the larger gauge, the comparative number of passengers to length of train being as 1·35 passenger per foot run of train on the 4 ft. 8½ in. gauge to 1·07 on the 2 ft. 6 in. gauge, and of minerals (coals) 0·63 to 0·42 ton per foot run. On a 2 ft. 9 in. gauge a passenger tank locomotive on two bogies, with a pair of cylinders and driving wheels of 4 ft. diameter, will take a train at a speed of 40 miles an hour, comprising 21 four-wheel carriages and 3 vans, containing 295 passengers, having a gross weight of 72 tons 18 cwt., with a length of train of 384 ft., including engine. On the 5 ft. 6 in. gauge the number of carriages for an equal number of passengers will comprise 7, and 2 vans for luggage, with gross weight of 107 tons, including engine and tender, and length of train of 320 ft., or as 0·77 on 2 ft. 9 in. gauge, to 0·93 on 5 ft. 6 in. gauge of passengers per foot run of train. For a branch or short

* The ruinous wear and tear on the Metropolitan lines in stopping and starting would to a great extent be spared by the lighter train on the narrow gauge.

† On the occasion of the Volunteer Rifle contest at Portmadoc, in August last, 840 passengers were conveyed in one train with one engine (bogie engine) from Portmadoc up the gradients to Duffws.

line on the small gauge with moderate traffic, there will be no necessity for the heavier class engines, and the headway of bridges and tunnels need not be so high as shown in the diagrams, but should be from 10 to 11 ft. for single line, and 11 to 12 ft. for double, instead of 12 ft. and 12 ft. 6 in. respectively, which will also still further reduce the works of tunnels and over bridges.

It may be fairly stated that there will be a saving of fully 35 per cent. by the smaller gauge line *under the most favourable circumstances as to section* over the 4 ft. $8\frac{1}{2}$ in. gauge, or with 2 ft. 9 in. gauge, 37 per cent. over the 5 ft. 6 in. gauge: besides, lines on the smaller gauge will take less time to construct than those of the larger. If such great advantage can be gained by construction of the narrow gauge to the *same* longitudinal section as the broader gauge, it is apparent that by adaptation of sharper curves offered by the narrow gauge system the reduction in works must inevitably be very much greater. The saving in long high viaducts, which are very numerous on the Indian lines, would be more than above shown for ordinary bridges. With the existing system, the piers and girders are required to be of great strength to stand the weight and concussion of heavy engines and rolling stock, which would be much lighter on the narrow gauge, and would not only be a saving in the quantity of material, but also in freight and insurance, which, on an average, amounts to 37*s.* 6*d.* per ton on all materials sent from England. This saving in freight and insurance on the lesser weight of materials and for permanent way, will be 104*l.* per mile.

The average cost of earthworks, bridges, and permanent way per mile on the Indian lines, is 11,000*l.* The minimum saving, taken at 37 per cent. by 2 ft. 9 in. over the 5 ft. 6 in. (having the same longitudinal section), would give a gain of 4070*l.* per mile, or less capital cost by 19,000,000*l.* on 4666 miles single lines of way, total length of lines already constructed in India, exclusive of the Oude and Rohilkund line.

The first cost of rolling stock, including locomotives, compared with number (or carrying capacity) of passengers and weight of goods conveyed as per Tables D, E, F, G, is of passengers as* 12·36 to 13·22, and of minerals and goods as 31·54 to 34·56, or $6\frac{1}{2}$ and $8\frac{3}{4}$ per cent. respectively in favour of the small gauge.

The rails and parts of other metals of the permanent way of a

* The estimated cost of rolling stock of small gauge as per Table F is high.

4 ft. $8\frac{1}{2}$ in. gauge line with a fair average traffic, will not last more than seven or nine years without renewing throughout, but that of a 2 ft. 6 in. gauge will, I have no hesitation in saying, last with the same traffic about twenty years. It is necessary here to mention an instance of the durability of rails when not subjected to undue weight upon them. About the year 1830 an Act was obtained to make a tramway or horse railway from the Nantlle slate quarries to Carnarvon, which was constructed in 1833 (a portion of this line has recently been absorbed into the Carnarvonshire Railway), on which the load, including weight of truck, rarely exceeds $2\frac{1}{2}$ tons, or $12\frac{1}{2}$ cwt. on a wheel; the rails have never been renewed, having sustained the wear of continuous traffic of 38 years. The rails are the old fish-belly section of 15 lbs. to the yard, laid on stone sleepers, with joint and intermediate chairs. The durability of these rails is not only demonstrative of the endurance of iron when not subject to undue weight, but also proves that corrosion takes place only to a very limited extent under continuous traffic, consequent on the repeated slight electric shocks caused by friction from the wheels on the rails.

In Ireland the lines are generally allowed to fall out of order both as to permanent way and rolling stock, and rendered unsafe to run at high velocities. It must be supposed that the railway companies do not possess the means to remedy so ruinous a state of things. I have no doubt such arises from the constructive system being on too large a gauge, which was apparently adopted more from an idea than practical utility, in a country, too, where the prospect of traffic is comparatively small, and where the unavoidable weight of locomotives on permanent way assumes more the character of a device of destruction than for the purposes contemplated.

I find in the minutes of evidence taken before the royal commission on railways in 1865 and 1866, that the following replies were made by George Willoughby Hemans, C.E. :—

Question 3764.—"Are you able to say whether the Irish lines of railway can be worked as economically as English lines with similar amount of traffic?"

Answer.—"I am sorry to say that I am afraid the Irish gauge is not, as has generally been supposed, a good invention. In my judgment, looking at the traffic of that country, it is a mistake.

"I think it is an impediment to the working of the lines economically. Had the traffic been as great or greater than it is in

England, I think it would have been a great advantage to have had a larger stock and more power for the locomotive; but the fact is that in Ireland the trade is small, and their rolling stock is heavier, and when the carriages are empty the dead weight is increased to a very considerable extent, I believe by quite 20 per cent."

Q. 3765 (Lord Stanley).—"By the difference which exists between a gauge of 5 ft. 3 in. and one of 4 ft. $8\frac{1}{2}$ in.?"

A.—"Yes; the carriages require to have heavier axles and heavier wheels, and heavier ironwork of all kinds; heavier frames for the carriages; and even if the carriages are full they only, with their gauge, accommodate four passengers abreast in the first-class carriages, which is done all over the Continent, and on some of the English lines on the narrow gauge; I am afraid that we have imposed a burden upon ourselves by that gauge rather than obtained a benefit."

It would be well that the attention of the Government was called to the necessity of repealing clause in Act 9 and 10 Victoria, chap. 87, sec. 1, as to the one gauge of 5 ft. 3 in. only for Ireland, and that a smaller gauge be also sanctioned for future railways in that country, and limited to a *fixed* narrow gauge.*

There is also a great advantage derived from the lightness of rolling stock on a small gauge in the marshalling of trains and shunting, besides reduced wear and tear and less liability to accidents when stopping at stations, and damage to trains and goods when shunting, and upon collision † occurring or on running off the line. At stations on lines with small traffic the porters will be able to shunt the trucks and carriages without the aid of either horse or engine, which has not only the effect of saving

* As regards altering the wider gauge to the narrow, the time and expense in effecting it would be slight. The mere shifting and fixing the rails of a single line to the narrow-gauge will only require 12 men to alter and lay one mile, at a cost of *5l.*, plus any new keys, spikes, &c., that will be wanted, or a total of *11l.* per mile. Thus 50 miles of line, divided into sections of 10 miles, could be changed with ease in one day by the employment of 120 men, at a cost of *550l.* I find that even much greater results have been accomplished in the same time in North America. The rolling stock could be disposed of to the wider gauge railways.

† The reason of less danger and damage arising from collision is, that a train is more easily stopped under brake power, from its being dispersed over a greater length of line. The carriages or trucks being more numerous, the number of successive blows on buffers is increased, and the force of each blow proportionately reduced. There being less dead weight, the train is stopped in less distance and less time.

time and expense, but affords fuller employment to the porters, obviating idle habit, under such circumstances so common in that class of officials.

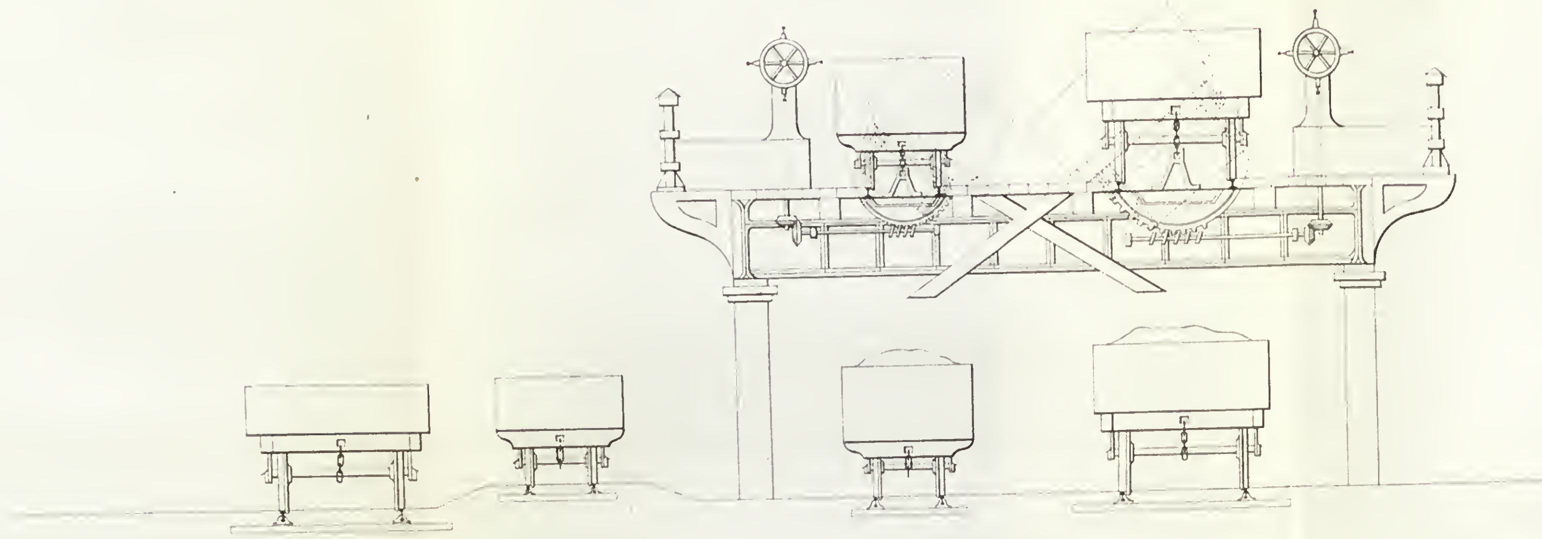
Amongst other advantages possessed by narrow gauge lines in the matter of dead weight, is in cases where trucks and carriages are lightly freighted; for instance, on a broad gauge a 4-ton truck conveying an agricultural implement, road carriage, or any general light goods which would only weigh some few hundredweights, while the conveyance would be performed on the narrow gauge truck of $1\frac{1}{2}$ ton, or a saving of $2\frac{1}{2}$ tons in weight hauled. The same also holds good where trucks so commonly on the large gauge are only partly filled.

An engine on the "Fairlie" principle, arranged with quadruple bogies and inside cylinders, can be made for 2 ft. 9 in. gauge for heavy gradient lines or heavy traffic to exceed a tractive power of 2000 tons on a level, at the same time possessing all the advantages of not increasing the weight on permanent way to each wheel beyond that of a double bogie or an ordinary four-wheel couple engine, *viz.* 3 tons, together with the other numerous advantages that the latter cannot possess.

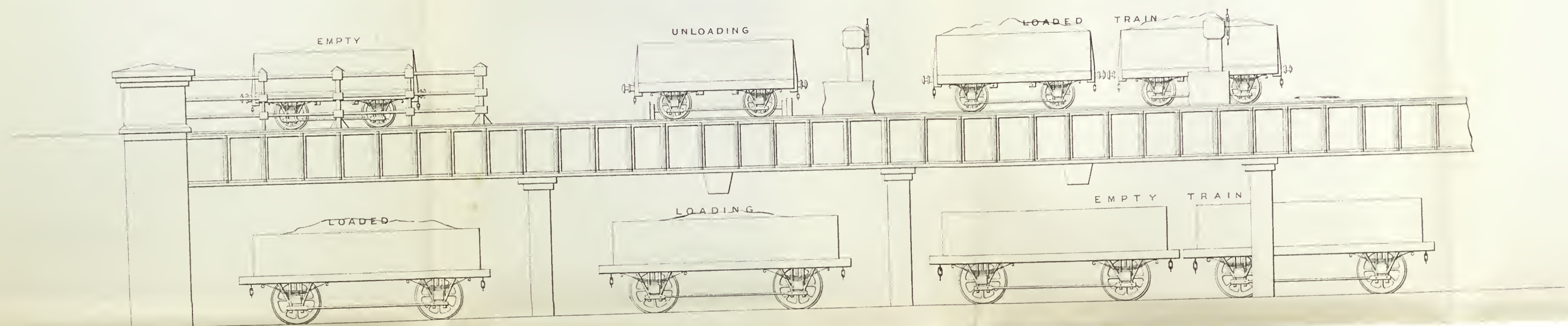
The break of gauge is looked upon as very objectionable by some engineers, who bring forward the fact of the Great Western Railway Company altering the gauge of their line from 7 ft. to 4 ft. $8\frac{1}{2}$ in. as sufficient evidence on this point. But if the case was reversed, it would not be likely that the gauge would be changed from a 4 ft. $8\frac{1}{2}$ in. to 7 ft.; in fact, there has been no proposal to do such a thing on any of the 4 ft. $8\frac{1}{2}$ in. gauge lines in connection with it. The main reason is the great expense of keeping up a line on such a broad gauge, and the directors see the advantage of altering it to the narrower gauge.

The chief objection made against small-gauge railways is that of transhipment. As to passengers, it will be only the same as with the existing system of uniform gauge, as they are obliged to change carriages at nearly all junction stations; and it would hold true with troops, as the trains would stop at some stations for the men to get refreshments; and it would only take the same time to move from or into a train of a narrow gauge as from or into that of a broad gauge; and the empty trains could then return for other troops. There would also be only the same

CROSS SECTION OF TIPPING PLATFORM



ELEVATION OF TIPPING PLATFORM



CROSS SECTION OF SIDINGS now being made near MINFORDD by the FESTINIOG RAILWAY Co. and the CAMBRIAN RAILWAY Co. for transhipment of SLATES, MINERALS and GOODS from all and on to the 2 feet and 4' 8½" gauges.

trouble to get trains to meet each other to the proper time at the junction stations, as with the ordinary gauge at the passing stations, and there would be rolling stock of the same total capacity on the narrow gauge as on the broad, for with either there would be enough for the traffic required to be carried, and no more duplicates wanted for one than the other.

Then in regard to goods, there would only be one point of transhipment at the junction of the two gauges, where all necessary appliances would be erected for the purpose, the charge for transhipment and loss of time on an article sent 1000 miles more or less would be infinitesimally small. Delay invariably takes place at junction stations of uniform gauge lines, the goods being detained waiting for trains off the through line for the junction line, or *vice versâ*. Supposing such junction line was on a narrow gauge, the same delay would occur, during which time the transhipment might be accomplished, and little or no loss of time would take place.

Of course, goods going from one point to the other within the length of uniform broad or narrow gauge would not require to be transhipped. The greater the length of line the less will be the comparative expense of the transhipment, and the original cost of the junction appliances will be divided over a greater number of miles.

Goods can be transhipped at the properly-constructed junction sidings from one line to the other by having the floors of the wagons on the same level, and the lid of one turned down on the door opening of the other. Also platforms between two lines for wheeling goods across, and turntables, &c. With heavy goods, stationary and travelling cranes will be used. The transhipment of minerals will be effected with a tilting cradle on a raised-road platform, at a proper and easy elevation, so that the contents of the trucks will be shot down to the receiving wagons below, as per annexed diagrams.

With these proper appliances, it is considered that the cost of transhipment will not exceed $\frac{3}{4}d.$ per ton for minerals, and $1\frac{1}{2}d.$ per ton for goods; nor can the delay caused by such operation be objectionable when compared with the enormous advantages gained in capital, cost of construction of line, and working expenses, particularly as the time required for transhipment is reduced to a minimum, and the objections against break of gauge is thus miti-

gated, so as to be of but little importance. The working expenses must vary according to the traffic that has to be performed. The part of working expenses comprised in station-masters, clerks, porters, signalmen, guards, and other officials, and telegraph, will be the same for a given and equal traffic on both lines, but the expenses in maintenance of permanent way and rolling stock will be quite 30 per cent. less on the small gauge than on the large gauge, arising from the reduction in weight upon each wheel, and from reduced dead weight or non-paying weight in rolling stock hauled, for same weight of minerals, goods, and passengers, together with a proportionate less consumption of fuel to gross weight of train.

The following are comparative tables of costs and receipts and of annual gain of a line of railway of 50 miles in length on 4 ft. 8½ in. and 2 ft. 6 in. gauge:—

COST AND RECEIPTS.

SINGLE LINE OF WAY ON 4 ft. 8½ in. GAUGE.

50 miles of line, including land, law, engineering, parliamentary administration, and every incidental expense for first-class railway, with permanent stations and telegraph complete (say will cost 8000*l.* per mile)	£ 400,000	
Cost of main sidings	1,876	
Rolling stock	39,844	£
		441,720

SINGLE LINE OF WAY ON 2 ft. 6 in. GAUGE.

50 miles of line, including land, law, engineering, parliamentary administration, and every incidental expense for first-class railway, with permanent stations and telegraph complete, say of 35 per cent. less than above, which represents the minimum advantage gained by the smaller gauge, at 5200*l.* per mile	260,000	
Cost of main sidings	1,572	
Additional cost at junction station for transhipment purposes	4,000	
	265,527	
Rolling stock	36,808	
		302,380
Difference in capital cost		139,340

ANNUAL TRAFFIC AND RECEIPTS OF EITHER LINE.

*Minerals,	100,000 tons	at 1¼*d.*	per ton per mile	26,041
*Goods,	60,000 „	1½*d.*	„ „	18,750
*Passengers,	200,000 „	1½*d.*	„ „	62,500
			Gross receipts	107,291

* If required, more than double this traffic can with facility be done on a 2 ft. 6 in. gauge (single way) of 50 miles.

COST OF TRANSHIPMENT OF MINERALS AND GOODS FROM AND TO THE 2 ft. 6 in. AND 4 ft. 8½ in. GAUGE LINES.

	£
Minerals, 100,000 tons at ¾*d.* per ton	312
Goods, 60,000 „ 1½*d.* „	375
Compensation for loss in transhipment ½*d.* per ton on goods and minerals	333
Total cost of transhipment and compensation for damage	1,020

ANNUAL GAIN BY 2 FT. 6 IN. GAUGE.

		£
5 per cent. interest on 139,340*l.* difference in first cost, per annum		6,967
5 per cent. interest on 139,340*l.* for reimbursement in 20 years, per annum		6,967
10 per cent. annual interest and reimbursement on difference of first cost of rolling stock before mentioned		303
		14,237
Deduct annual cost of transhipment and compensation at Company's expense		1,020
Annual saving by interest on difference in first cost		13,217
I think I may fairly venture to assume that the working expenses taken at quite an extreme estimate will not exceed 35 per cent. of the receipts on the small gauge, but that of the larger gauge line will be at a moderate rate, 45 per cent.		
Then 45 per cent. on receipts of 107,291*l.*		48,280
Then 35 per cent. on receipts of 107,291*l.*		37,551
Difference and saving in working expenses		10,729
Saving in interest on difference in cost of first construction and rolling stock by narrow gauge line		13,217
Annual gain for the first 10 years		23,946
The cost of renewal of permanent way of 4 ft. 8½ in. gauge at the end of 10 years (quite the outside durability) will be as follows:—	£	
Cost of 50 miles of new permanent way, including main sidings	112,101	
Value of old rails, fish-plates, bolts, chairs, pins, sleepers, keys, ballast = 902*l.* per mile × 50 miles + 700*l.*, sidings to be deducted	45,800	
	66,301	
Less by cost of renewal of portion of permanent way of 2 ft. 6 in. gauge line per mile of sleepers, keys, part chair-pins, and ballast, 314*l.* per mile × 50 miles + 470*l.* sidings	16,170	
Difference in cost of the 4 ft. 8½ in. permanent way after the first 10 years	50,131	
5 per cent. interest and 5 per cent. for reimbursement of expenditure in 20 years on 50,131*l.*		5,013
Total annual saving after the first 10 years by 2 ft. 6 in. gauge over 4 ft. 8½ in. gauge line		£28,959

The accompanying diagrams (Plates 10 and 11) show the comparisons between lines on 5 ft. 6 in. gauge and 2 ft. 9 in. gauge,

with *proportionate* curves for both lines through a moderately undulating country, following the contour of the hill-sides, and showing difference in earthworks and length of lines between given points A, B. The wheel base of carriages and trucks to be *proportionate* for each line, or for the 5 ft. 6 in. gauge twice that of the 2 ft. 9 in. gauge, so that the friction of wheel flanges against rail and drag friction of wheel tyres on inner rail of curves are the same with one as the other. If a line of 5 ft. 6 in. gauge, with bogie engines and bogie carriages, was taken over the same ground, having wheel base of engines and carriages half of that for the blue line of 5 ft. 6 in. gauge, or the same as that for the 2 ft. 9 in. gauge line shown in red, then the comparative line is as marked in green, and the carriages will run on this line with the same amount of drag of inner wheels on rails, less half the friction or resistance of wheel flanges against rails. A proportionate greater play between gauge of wheel flanges and gauge of rails is admissible with the smaller wheel base on the narrow gauge, and still further reduces the flange resistance.

By the application of bogie carriages and engines for the narrow gauge of 2 ft. 9 in. (Fig. 1), the drag and friction are reduced to almost a nullity, independent of secured steadiness and numerous other advantages gained by the bogie system, too well known to need further comment by me.

The difference in length between the green line of 5 ft. 6 in. gauge and the red line of 2 ft. 9 in. is 6 chains, and that of the blue line 5 ft. 6 in. gauge, 8 chains in the mile, so that, through an ordinary hill country, having a continual succession of curves, there would be about one additional mile to every ten to construct on the 2 ft. 9 in. over that of the 5 ft. 6 in.; but practically there would not be half so much for a line of any length, as there would be many straight portions and easy curves to both lines; besides it would, from the various and peculiar features in the sideland ground, sometimes be found better to somewhat increase the depth of cuttings and fillings, and to reduce length by widening the curves. The increased length, however, is gained just where it is wanted (*viz.* hill countries), as in traversing mountain districts, length is a material object as a means of reducing the gradients.

Supposing a line on 4 ft. 8½ in. gauge was taken through the high mountainous districts between Portmadoc and the Festiniog

DIAGRAM PLAN AND SECTIONS

OF LINES OF RAILWAYS ON SIDELAND GROUND

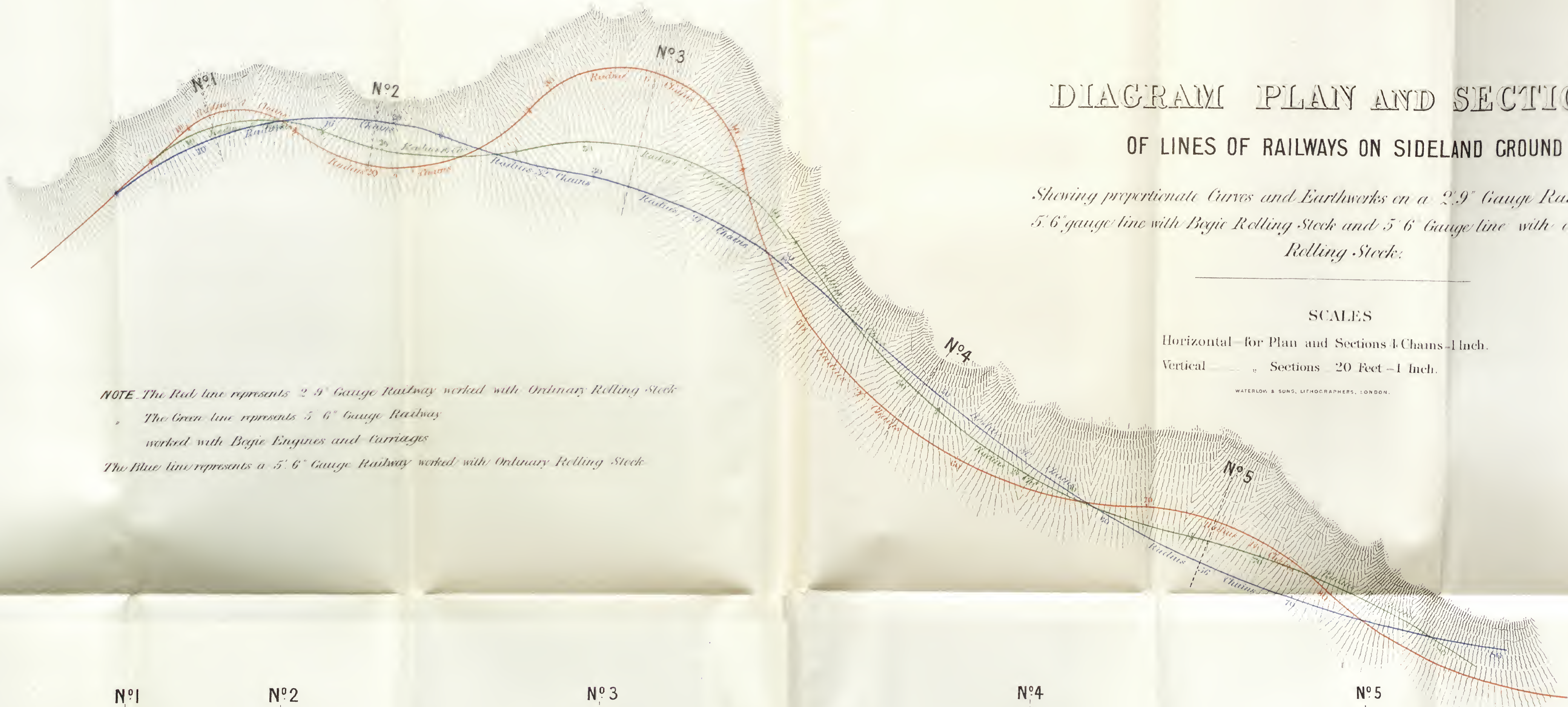
Showing proportionate Curves and Earthworks on a 2' 9" Gauge Railway; a 5' 6" gauge line with Bogie Rolling Stock and 5' 6" Gauge line with ordinary Rolling Stock.

SCALES

Horizontal — for Plan and Sections 4 Chains = 1 Inch.

Vertical — „ Sections 20 Feet = 1 Inch.

WATERLOW & SONS, LITHOGRAPHERS, LONDON.



NOTE. The Red line represents 2' 9" Gauge Railway worked with Ordinary Rolling Stock

„ The Green line represents 5' 6" Gauge Railway worked with Bogie Engines and Carriages

The Blue line represents a 5' 6" Gauge Railway worked with Ordinary Rolling Stock

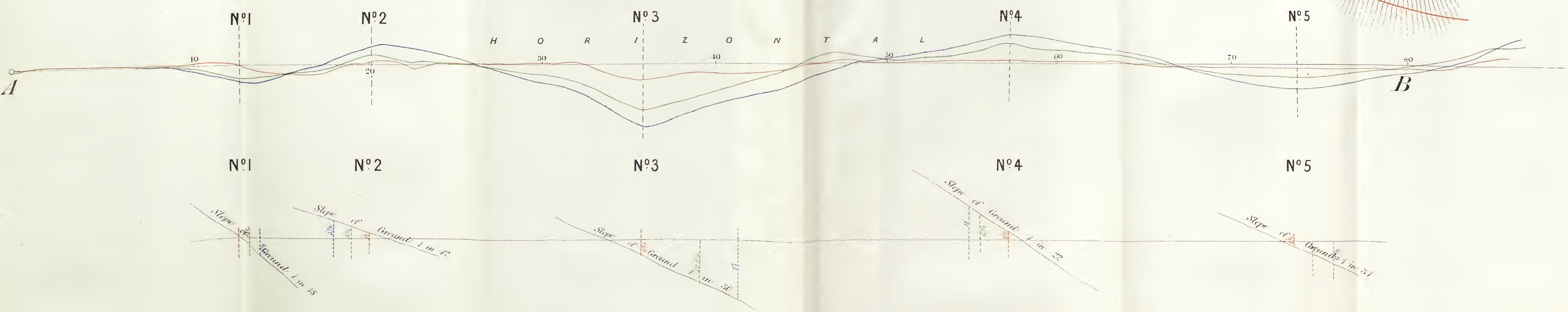
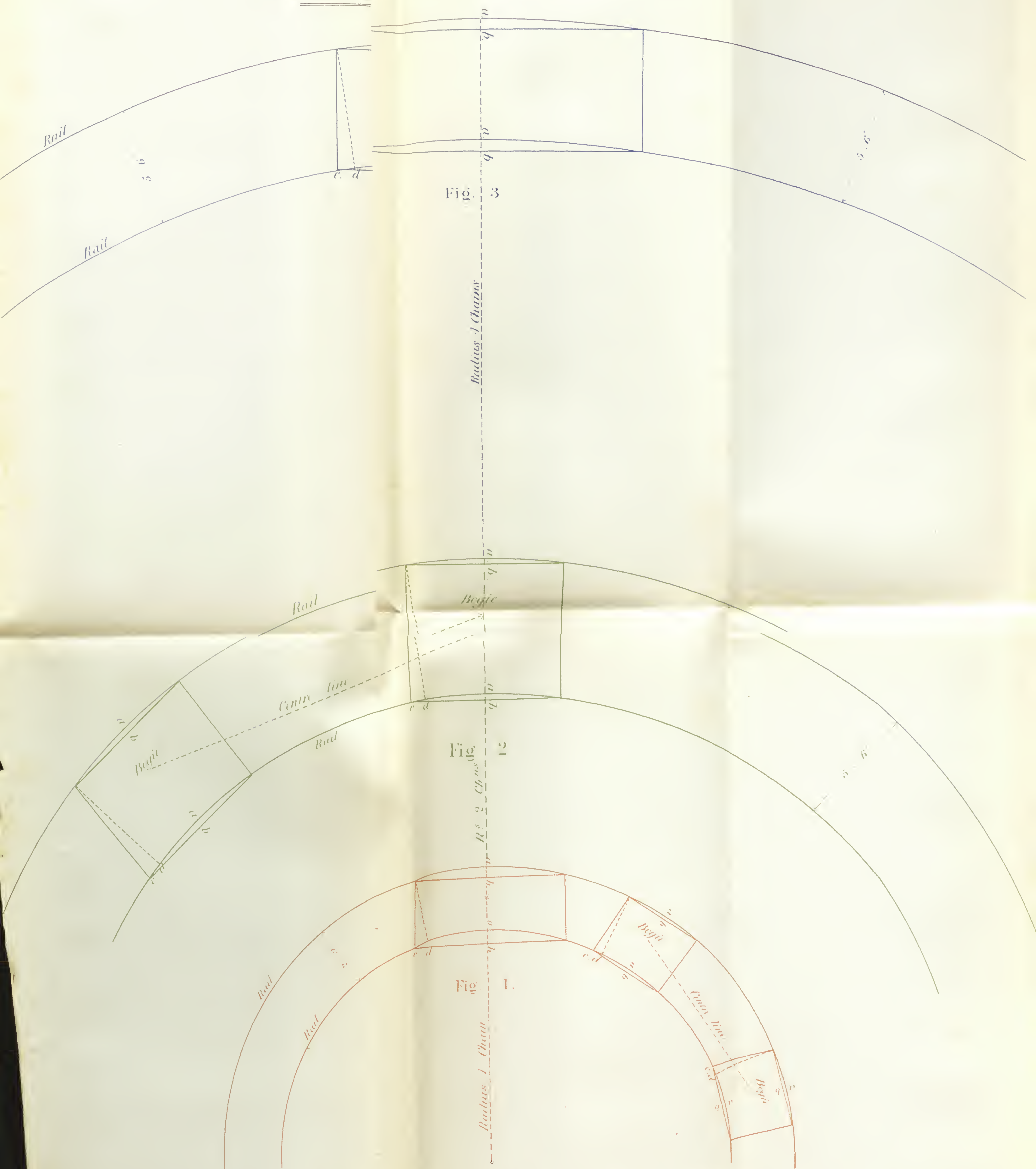


Diagram shewing Sharp Radii Curves on 5' 6" and 2' 9" gauge for illustrating the "Drag" and Flange Resistance

Scale of Radii of Cu[rves] 3 inches to 1 Chain & Wheel base 5 Ft to 1 inch



The Versed Sine a.b Figs 1, 2, 3 = The Flange resistance or nip against Rail

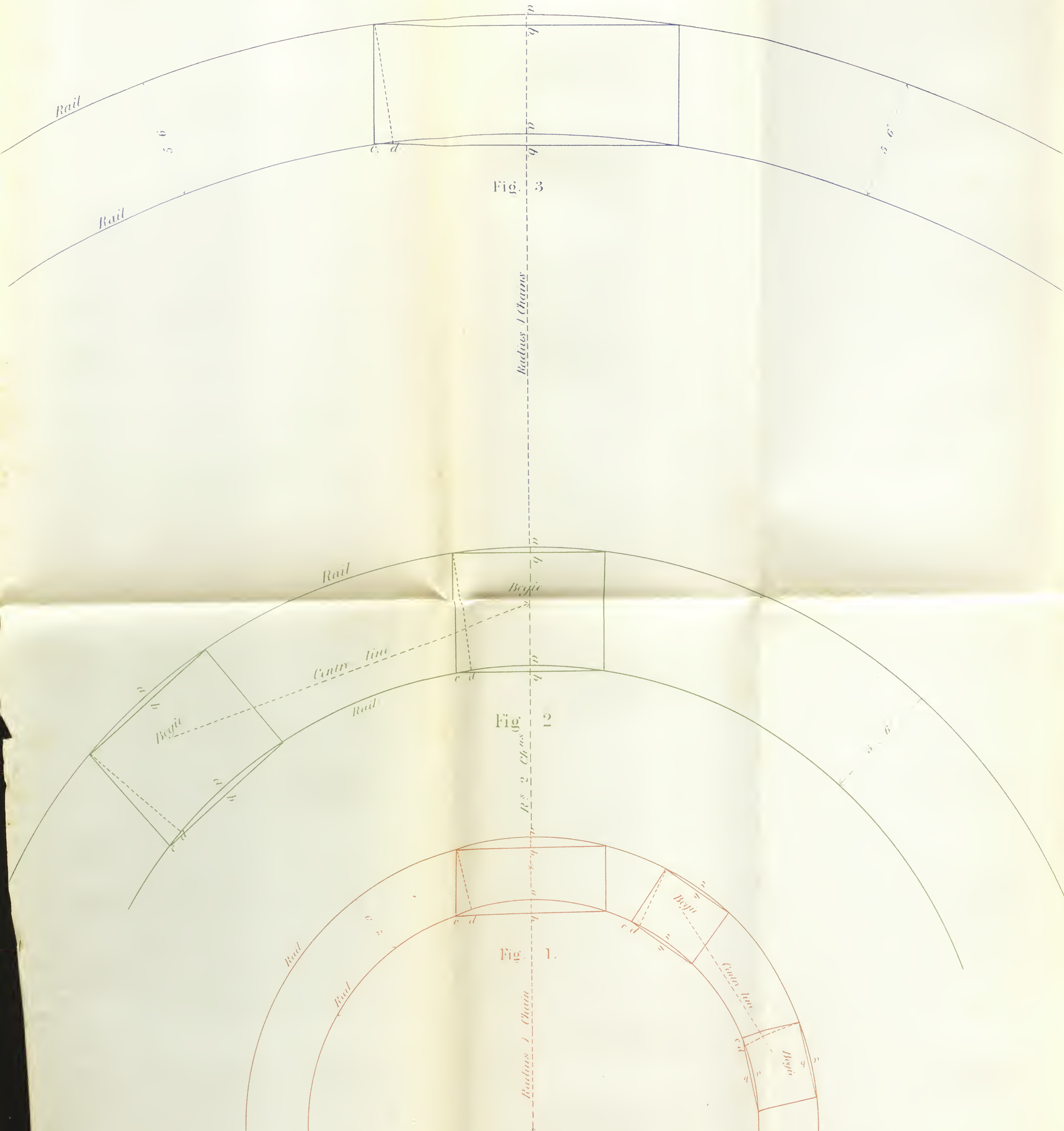
c.d Figs 1, 2, 3 = The Drag resistance on inner Rail

The Versed Sine a.b Fig 1. = a.b. Fig 3 = a.b × 2 Fig 2.

a.b of Bogies Fig 1 = $\frac{a.b}{4}$ of Figs 1 and 3 and = $\frac{a.b}{2}$ of Fig 2.

Diagram shewing Sharp Radii Curves on 5' 6" and 2' 9" gauge for illustrating the "Drag" and Flange Resistance

Scale of Radii of Curves 3 inches to 1 Chain & Wheel base 5 ft to 1 inch



The Versed Sine a. b. Figs 1 2 3 – The Flange resistance or nip against Rail
c. d. Figs 1 2 3 – The Drag resistance on inner Rail
The Versed Sine a. b Fig 1 – a. b Fig 3 – a. b × 2 Fig 2.
a. b of Bogies Fig 1 = $\frac{a.b}{4}$ of Figs 1 and 3 and – $\frac{a.b}{2}$ of Fig 2.

slate quarries, with *proportionate curves* to those of the Festiniog 2 ft. gauge line, the extent of the works to formation level would exceed eight times that of the Festiniog Railway; and to perform the annual traffic of 140,000 tons, 24,500 tons of non-paying weight, over and above what is now carried, would have to be hauled up the gradients, besides the additional wear and tear in the down journey by the use of brakes through the increased weight of the larger trucks.

RAILWAY GAUGES.

Extract from 'Engineering,' November 18, 1870.

From C. E. SPOONER *to the* EDITOR *of* 'ENGINEERING.'

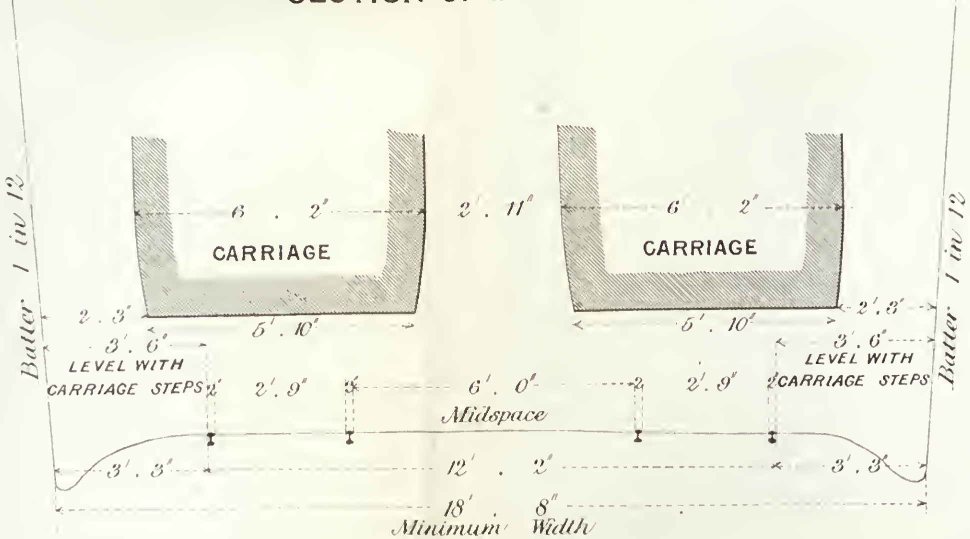
SIR,

I have read with great interest the articles in your valuable paper on this subject, and shall feel obliged if you will insert the following observations and accompanying diagrams in regard to the same.

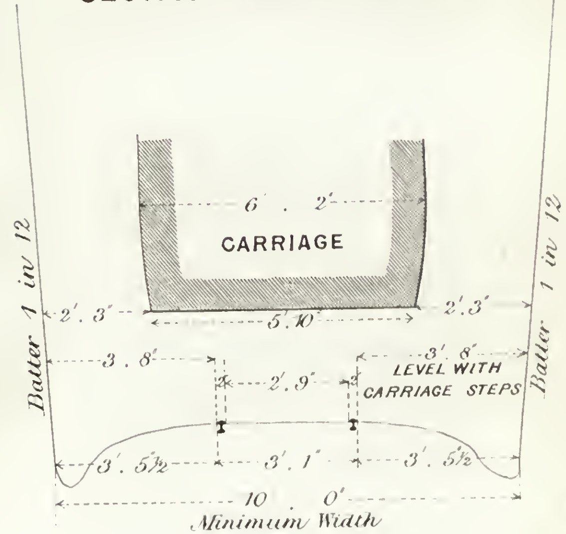
I entirely agree in your views that the broad gauges will eventually be altered by sections to the narrower in India and other countries. It is therefore of importance that the narrow new gauge be so arranged that a double line can be laid on the broader gauge single line formation, with as little expense in extra works as possible. This can be done with a 2 ft. 9 in. gauge. The carriages (with sliding doors) to be made 6 ft. wide and the trucks up to 6 ft. 3 in. wide, which would be sufficient for all articles usually conveyed by railways. On the Festiniog Railway of 1 ft. 11½ in. gauge, with trucks from 3 ft. 5 in. to 4 ft. 5 in. wide, the machinery required for the use of the quarries, including portable engines, boilers, &c., are conveyed with ease.

It will be seen from the diagrams, that horse boxes can be constructed for a 2 ft. 9 in. gauge line to carry two horses, and cattle trucks to carry five beasts. By the use of bogie trucks, the number carried is increased to six horses and ten beasts, with greater steadiness and comfort to the animals. Such construction would be preferable upon any gauge. It will be observed that movable iron fodder troughs are attached to the cattle trucks, and the trucks so arranged that somewhat more room is allowed for the beasts as they stand than is usually the case. Chopped fodder in sacks can be carried with the man in charge of the animals in the compartment provided at the end of the truck, who will feed and water them on the journey when stopping at stations. The subject of feeding cattle on long journeys has already been brought before

SECTION OF DOUBLE LINE



SECTION OF SINGLE LINE

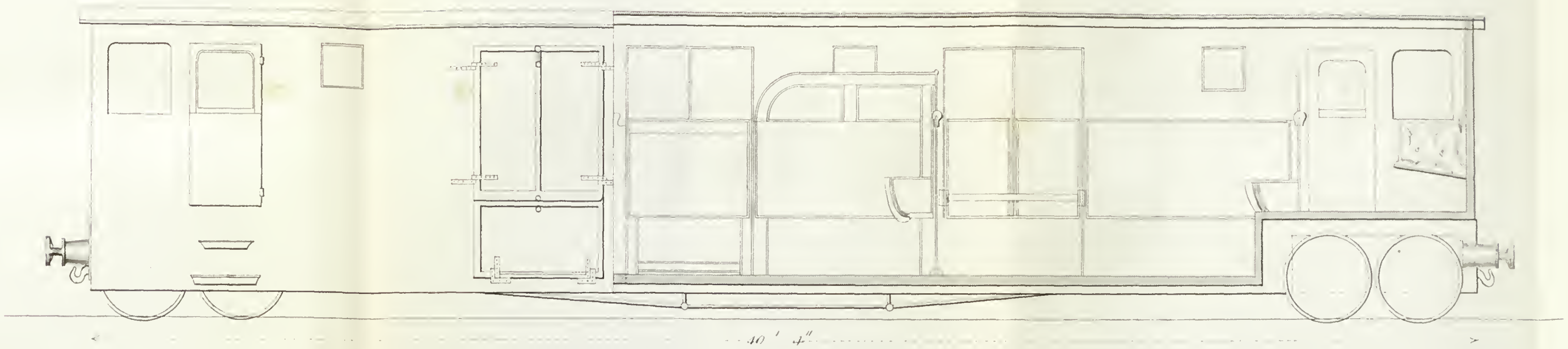


Scale, ¼" = 1 foot.

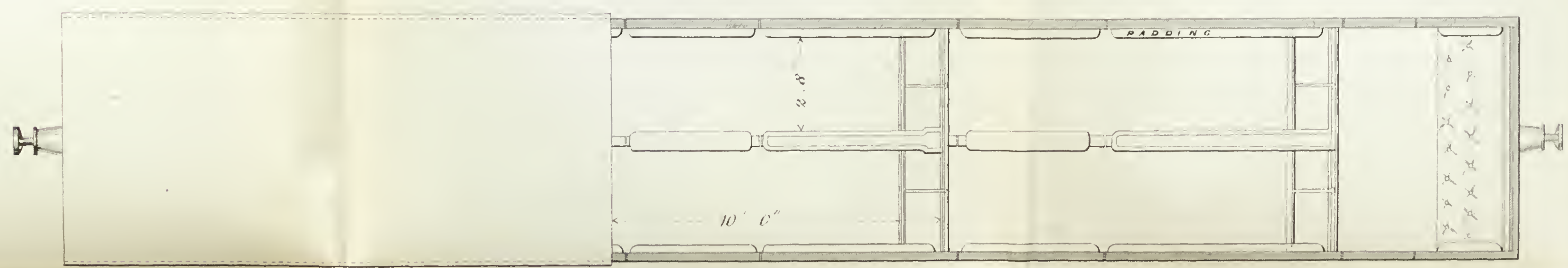
BOGIE HORSE BOX.

For 2' 9" Guage.

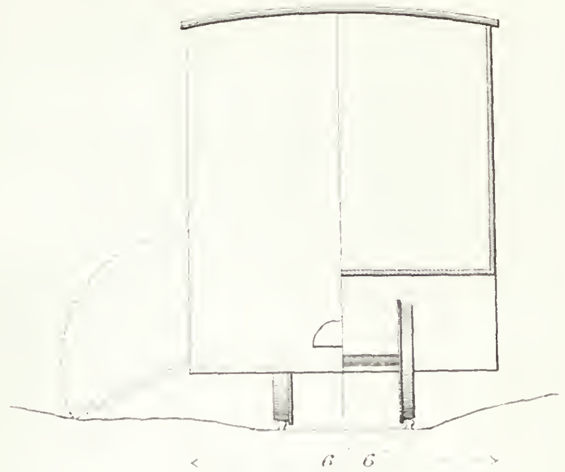
Elevation



Plan



End Elevation



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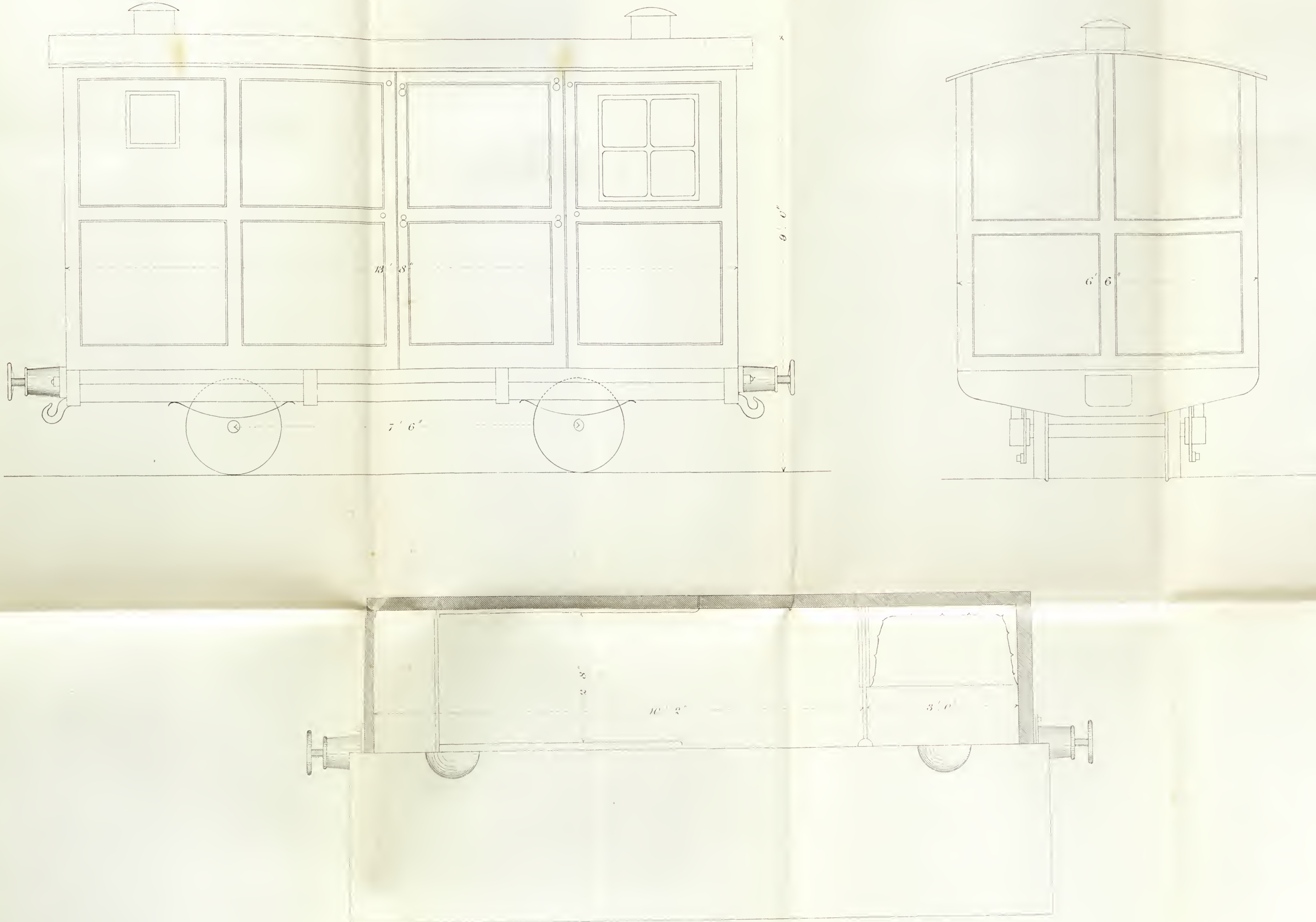
HORSE BOX.

For 2' 9" Gauge.



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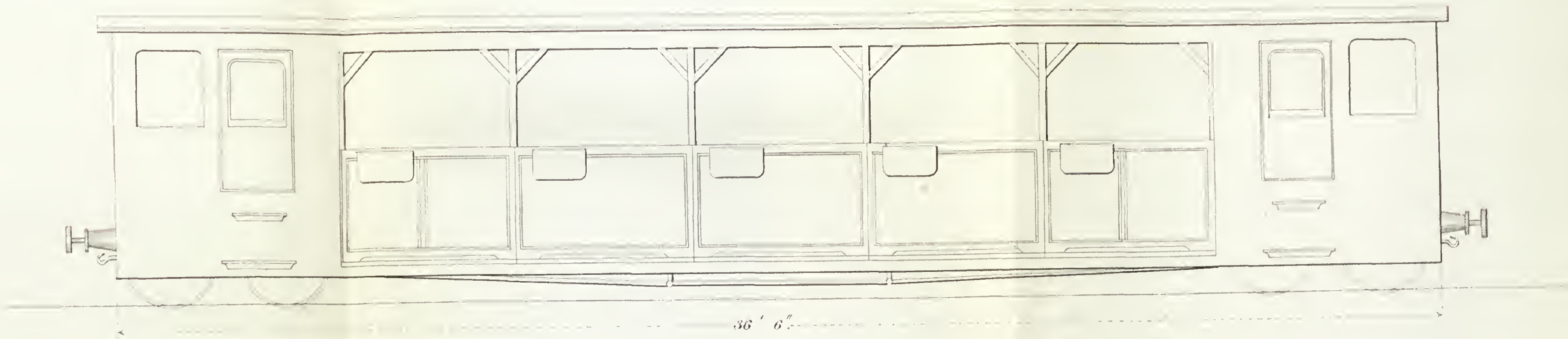
Bogie Cattle Truck

For 2..9 Guage.

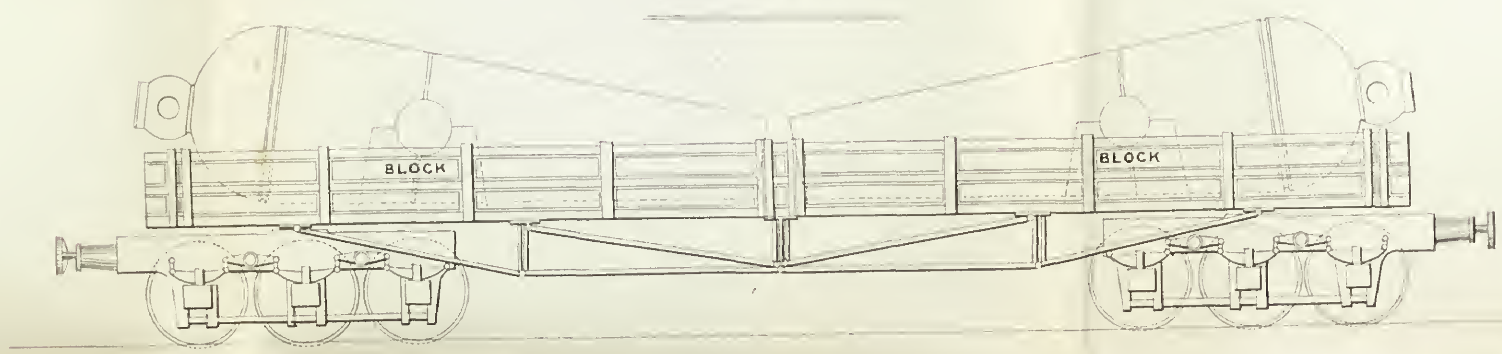
Elevation.



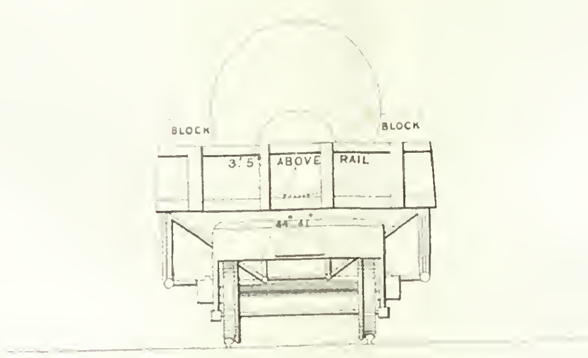
Heavy Bogie Goods Truck

AVAILABLE FOR ORDNANCE

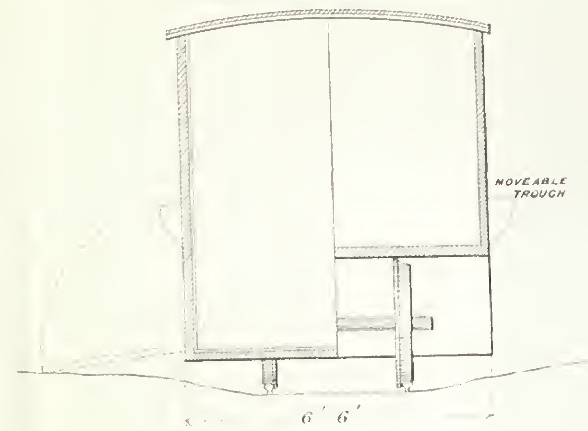
Elevation.



End Elevation of Ordnance Truck.

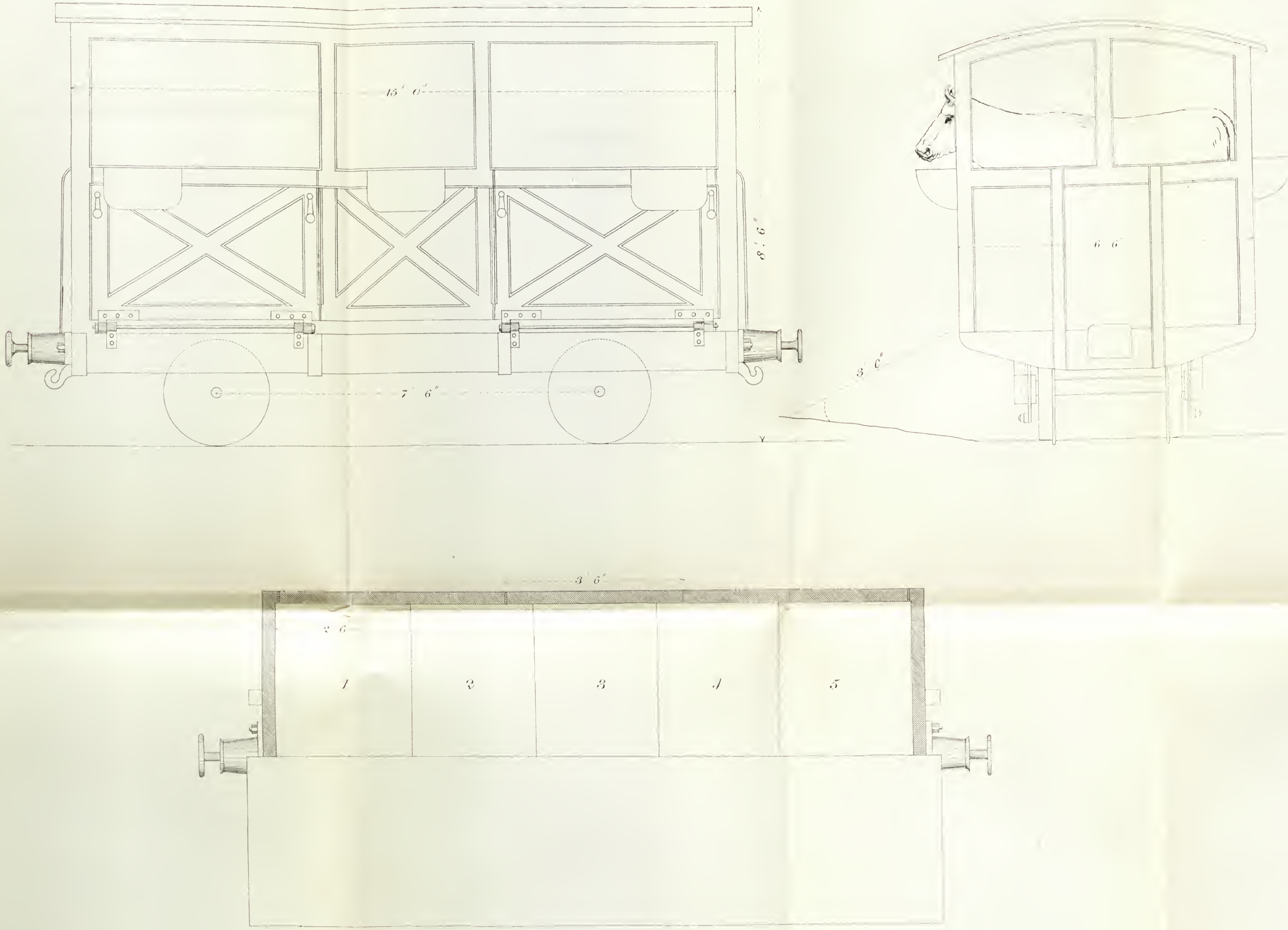


Transverse Section of Cattle Truck.



CATTLE TRUCK.

For 2' 9" Gauge.



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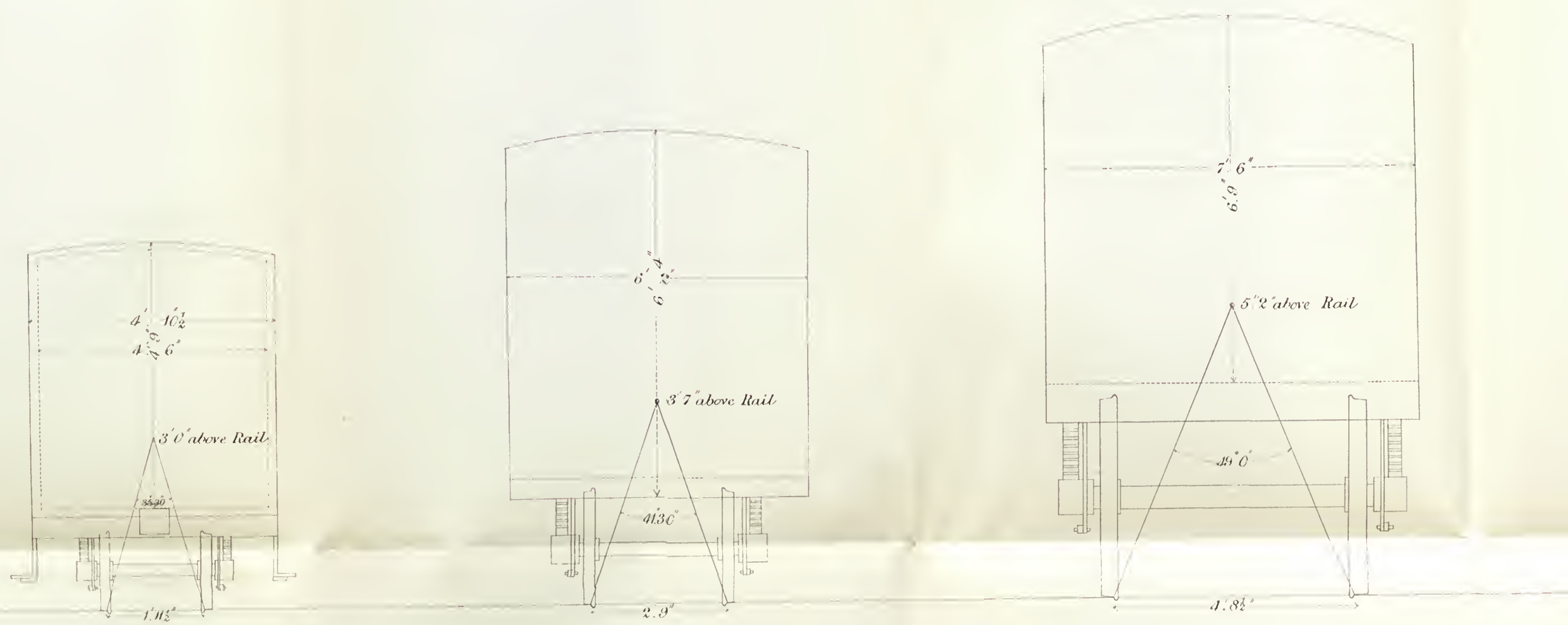
End View shewing Relative Stability of Passenger Carriages.

on 4'. 8½". 2'. 9" and 1'.11½ Gauges.



Waterlow & Sons, Lithographers, London

railway companies, and just complaints made as to the injury and loss sustained from overcrowding and want of food.

In regard to the stability of rolling stock, the accompanying diagrams show a comparison in this respect between 1 ft. 11½ in., 2 ft. 9 in., and 4 ft. 8½ in. gauges, assuming the centre of gravity to be at the level of the seat in each carriage. On the 1 ft. 11½ in., with a height above the rail of 3 ft., the angle of stability is 35½°; on the 2 ft. 9 in., with a height of 3 ft. 7 in., the angle is 41½°; and on the 4 ft. 8½ in. gauge, with a height of 5 ft. 2 in., the angle is 49°. There has not yet been an instance of a Festiniog Railway carriage being blown over, though the line is in a country subject to severe storms, and the trains traverse very sharp curves, which necessarily entail a considerable super-elevation of the outer rail. It will thus be seen that in actual practice no fears need be entertained respecting the stability of the carriages used on a 2 ft. 9 in. gauge railway. With carriages on the 4 ft. 8½ in. gauge, the centre of gravity is often at a greater height in consequence of luggage placed on the top with the necessary covering, whereas it is intended that all luggage on the narrow gauge be placed in the vans.

PORTMADOC, NORTH WALES,
NOVEMBER 10, 1870.

NARROW GAUGE ROLLING STOCK.

Extract from 'Engineering,' November 18, 1870.

"At the present time, when the advantages and disadvantages of narrow gauge railways are attracting so much attention, numbers of our readers will peruse with interest the letter on 'Railway Gauges,' from Mr. C. E. Spooner, which we publish on another page of the present issue. As the engineer of the celebrated Festiniog Railway, Mr. Spooner has had much experience in the practical working of a line of extremely narrow gauge, and as he is, moreover, well known to be an earnest advocate for the construction of railways of a much narrower gauge than that generally adopted, his remarks on the subject are well worthy of attention.

"In his letter just referred to, Mr. Spooner deals principally with the rolling stock for a line of 2 ft. 9 in. gauge; and he has forwarded us a series of designs for cattle trucks and horse boxes for such a railway, these designs (which we illustrate on page 364) being no doubt intended as a reply to the objections made by us to the 2 ft. 9 in. gauge in an article on 'Railway Gauges,' which appeared on page 299 of our number of the 21st ult. In the article just mentioned, we stated that a gauge of 2 ft. 9 in. was not, in our opinion, sufficiently wide for the convenient conveyance of horses and artillery, and that the horse boxes which would have to be used on it would not have the amount of lateral stability which it is desirable railway vehicles should possess. We have carefully examined Mr. Spooner's designs; but—although we believe that Mr. Spooner has done, perhaps, the best which could be done on such a gauge—we do not find that the rolling stock he proposes possesses such qualities as would induce us to modify the opinion we have just expressed.

"Let us, for instance, consider the horse boxes, for which Mr. Spooner furnishes two designs, the one—shown by Figs. 6, 7, and 9 on page 364—being a vehicle carried on four wheels in the usual way, and the other—represented by Figs. 1, 2, and 3 on the same page—being for a long horse-box carried on a pair of four-wheeled

bogies. The first-mentioned horse box is intended for two horses, and as the width of the vehicle has been made 6 ft. 6 in., and the length of that portion devoted to the horses 10 ft. 2 in., there is ample accommodation for the animals as far as floor area is concerned. The height of the floor above rail, however, is about 2 ft. 4 in., and as the total height of the vehicle is 9 ft., there is left an inside height of but about 6 ft. 7 in. at the centre and 6 ft. at the sides, heights which are quite insufficient for the safe conveyance of horses. As designed by Mr. Spooner, the horse box has a side area of $102\frac{1}{2}$ square feet, and if we take the weight of the vehicle loaded as 4 tons, we shall find by a simple calculation that the pressure of wind on the side just capable of balancing the righting moment due to the weight would be about 28 lbs. per square foot. The vehicle is however, as we have said, deficient in height, and if we increase the latter dimension to 7 ft. inside at the sides—a moderate height for a horse box—the side area will become 116 square feet, while the centre of pressure will be raised from a point 5 ft. 3 in. to one 5 ft. 9 in. above rail level, and the wind pressure required to just overcome the righting moment due to the weight will then be found to be but about $18\frac{1}{2}$ lbs. per square foot. Even if the weight of the vehicle and its load be increased to 5 tons, the pressure of wind required to just overcome its stability would be but about $23\frac{1}{2}$ lbs. per square foot. These calculations are all made on the supposition that the horse box is fully loaded; if it was empty, or if it contained but one horse, and that horse happened to be to leeward, the resistance would be considerably diminished.

"Turning now to the horse box carried on a pair of bogies, we find that in this also Mr. Spooner has given ample floor area for the six horses he proposes to carry, and besides this he has also made the height almost as great as we have stated it to be necessary, the heights inside, at the sides and centre, being about 6 ft. 9 in. and 7 ft. 2 in. respectively. As the height of the vehicle is but 8 ft. 6 in. from rail level to top, this increased height inside has to be obtained by lowering the floor, and this latter has been placed but 1 ft. 3 in. above the rails for all that portion of the length of the vehicle to be occupied by the horses. At the ends, however, the floor level has been raised to obtain room for the bogies, as shown. Of course, by the adoption of this

arrangement, the centre of gravity of the vehicle has been kept very low, as has also the centre of pressure of the wind on the side area, and the stability of the horse box has been correspondingly increased; but, on the other hand, the arrangement involves certain practical difficulties of construction which we do not see the way to satisfactorily overcome. Thus, the total length of the body of the vehicle is 40 ft. 4 in., and the distance from centre to centre of bogies 34 ft. 4 in., and this great length between the points of support will evidently necessitate the employment of a strong longitudinal framing to prevent sagging. The sides of the central portion of the vehicle being each practically cut away at two points by openings for the doors, it follows that they cannot be depended upon for giving the required rigidity, and this must consequently be obtained solely by giving sufficient strength to the under framing. But here comes the difficulty; the floor being but 15 in. above rail level, there is but a depth of 9 in. or so available for the framing, and we must confess that we do not see how within this depth a framing of the necessary strength could be constructed without employing a quantity of material quite out of place in the light class of rolling stock to which the horse box we are considering is supposed to belong. It must be remembered, in considering this matter, that the framing not only has to form a girder over 34 ft. long, carrying the horses occupying the central portion of the vehicle, but it also has to withstand the combined compressive and bending strains due to the action of the buffers, the centre line of the latter being about 6 in. above the floor level. In shunting a long train the strains to which the framing of a horse box like Mr. Spooner's would be exposed would be very severe.

"There is also another objection to this bogie horse box, and that is that it carries too many horses. In the event of cavalry or artillery having to be transported it would no doubt be convenient to carry six horses in one vehicle, but in ordinary times, when single horses often have to be conveyed, the use of bogie horse boxes would lead to the dragging about of a very large percentage of unpaying load. Such a horse box as that designed by Mr. Spooner would weigh, we should anticipate, at least 8 tons, and probably more.

"We now come to the cattle wagons for which Mr. Spooner has also sent two designs—one for a four-wheel wagon capable of carry-

ing five beasts, and the other for a long double bogie wagon with accommodation for ten beasts. To both these designs, we regret to say, we have objections to make. It will be seen that in both wagons Mr. Spooner intends the beasts to stand transversely (as shown in the end view, Fig. 10, page 364), and he has adopted the outside width of 6 ft. 6 in. for his vehicles with a view of enabling this method of stowage to be used. Now, 6 ft. 6 in. is, we consider, an extreme width for wagons intended to run on such a narrow gauge as 2 ft. 9 in., and to carry such an unstable cargo as cattle; but for the present we will allow that such a width is permissible. Even with this extreme width, however, the clear width inside is but 6 ft., and to enable cattle to be carried in this width Mr. Spooner has been compelled to keep down the height of the sides of his wagons to 3 ft., thus leaving, in the case of the four-wheeled wagon, a space of about 2 ft. 4 in., and in the case of the bogie wagon a space of about 2 ft. 8 in., between the tops of the doors and the cant-rail, through which the cattle can place their heads, as shown. Now, all railway men who have had experience on lines carrying large quantities of cattle will well know that beasts could not be safely transported in trucks constructed in this way. The smaller and more active beasts would be continually making escapades through the side openings, as we have ourselves known them to do through much smaller openings situated more than a foot higher above the floor level. Again, the height from the floor level to the under-side of the cant-rail is in the case of the four-wheeled wagon but about 5 ft. 4 in., and this height is so cramped that with many kinds of cattle there would be very great difficulty in loading the wagons at all. In the case of the bogie wagon the height is greater, namely, about 5 ft. 8 in., and so far it is better for loading, but the sides being necessarily kept down to about 3 ft. in height, there results a larger opening for the escape of the cattle. Another point worth considering is that one of Mr. Spooner's wagons when loaded would measure quite 8 ft. wide from outside to outside of the heads of the cattle, and thus the widths of tunnels, &c., required to permit it to pass would be as great as would be necessary for vehicles adapted for a much wider gauge.

"We may remark here that the general system of construction of the bogie cattle wagon is similar to that of the bogie horse box,

and the height from rail to floor is also the same in the two cases. Inasmuch, however, as the cattle wagon is somewhat shorter than the horse box, and as, moreover, the sides are less cut away near the middle of its length there would be rather less difficulty in obtaining the necessary rigidity of framing in the former than in the latter instance. Even in the case of the cattle wagon, however, we fear that a frame of the necessary strength would be extremely heavy.

"The comparative diagrams furnished by Mr. Spooner, showing the stability of carriages of lines of 1 ft. 11½ in., 2 ft. 9 in., and 4 ft. 8½ in. gauge, respectively, will be regarded with much interest."

NARROW GAUGE RAILWAYS.

Extract from 'Engineering.'

From C. E. Spooner *to the* Editor *of* 'Engineering.'

Sir,

The subject of railway gauge is once more attracting the attention of the engineering world. It is twenty-five years since the first "battle of the gauges" was fought between the advocates of the 7 ft. and those of the 4 ft. 8½ in. gauge, with the well-known result of neither gaining a victory at the time, and of both carrying out their ideas into practical operation. Looking back to that period, it is interesting to read over the conflict once more, and note what the advocates of each had to say of their respective gauges. They were then without any previous experience or knowledge to guide them in deciding a matter of so much importance, and it was, therefore, difficult for them to arrive at a right conclusion. The broad gauge appeared to many the most advisable from the large capacity and steady running of the rolling stock. They did not take into consideration that, though it was well enough for the public, others had an interest and heavy stake in the matter, *viz.* the shareholders, and that if the latter were not successful the public would also be a loser in the long run. The advocates of the 7 ft. gauge claimed the following advantages by its adoption :—

1. Attainment of a high rate of speed.

2. Increased facilities for the use of larger and more powerful locomotives.

3. Admitting low centres of gravity for rolling stock, and giving increased stability and steadiness of motion.

The objections were :—

1. The increased cost of construction.

2. Greater weight of rolling stock, and liability of axles breaking from their great length.

3. Greater friction in passing round curves.

As regards the first, it was argued that there was only an

excess of 7 per cent. in earthworks and land over the 4 ft. $8\frac{1}{2}$ in., and that the carriages were lighter in proportion to load carried, that in practice axles did not break, and that, as regards friction, it did not hold true with the broad curves set out on the Great Western. It will be noticed that the arguments used at present by the opponents of the narrow gauge are much the same as those formerly used in favour of the 7 ft. gauge and against the 4 ft. $8\frac{1}{2}$ in. gauge. The result eventually was that, though there was some truth in the advantages claimed for the broad gauge, still the objections were much more cogent, and no more lines of that description were constructed. For many years railway promoters were content with constructing lines on the standard gauge of 4 ft. $8\frac{1}{2}$ in. without ever considering whether greater advantages could not be gained by adopting a smaller gauge. Though the high hopes entertained of the great benefits of cheap and quick communication have been fully realized, and the increase in traffic beyond anything anticipated, the return on capital outlay to shareholders is inadequate, which has had the effect of stopping investment in railways to a great extent. There are, however, many districts in this country, and large tracts in the colonies, which require railway communication to develop their resources, but there is no prospect that many lines on the existing system will be made, as no return can be expected on the outlay. It appears, therefore, that railways of the future should possess the following capabilities:—

1. Moderate cost of construction.
2. Moderate cost of maintenance and working.
3. To have the necessary stability, and to run at speeds required for public dispatch, with safety and comfort to the passengers.
4. Capacity to carry all the traffic required, and available for any increase in the traffic that may eventually take place.
5. Capacity to carry troops, ordnance, and military stores, and be available for all purposes during time of war.

As the first and second requirements are governed to a great extent by the gauge, and it has been proved that gauges from 7 ft. to 4 ft. $8\frac{1}{2}$ in. are needlessly wide, it is evident that railways on a narrow gauge must be constructed. The question, therefore,

is, what is the gauge that will nearest fulfil the above requirements? This is naturally a subject of controversy, but it is to be hoped that only one narrow gauge will be decided upon for the same country. From the experience gained with extreme wide and narrow, as well as intermediate gauges, engineers are at present in a much better position to determine the best gauge for the future than was the case when the first had to be decided upon.

In the paper I read before the Inventors' Institute, in 1865, "On Narrow Gauge Railways," I advocated a 2 ft. 6 in. or 2 ft. 9 in. gauge for future lines. Since then I have gone fully into the matter, and taking into consideration that it would be advisable to be able to construct locomotives with inside cylinders, and that in hot countries more space is required for passengers than in temperate climates, and having gone carefully into the dimensions and capacity of rolling stock, and the nature of the traffic, I have come to the conclusion that the 2 ft. 9 in. gauge is the most advisable for India, and will fully meet all requirements.* From my experience in working the 1 ft. 11½ in. gauge, I deduce the following to show the sufficiency of a 2 ft. 9 in. gauge:—

1. That the cost in first construction in earthworks, bridges, tunnels, &c., depends on the gauge. In regard to the construction there is another matter for consideration with Indian lines which is of great importance—that is, being able to lay down a double line of the 2 ft. 9 in. gauge on a single line formation of the 5 ft. 6 in. gauge when required without altering bridges, viaducts, tunnels (as on all the Government lines these are made for a double line), or earthworks, without any extra expense except laying down the permanent way.

2. That the cost of maintenance of rolling stock and way will be low, consequent on the small weight on each wheel, and less damage to rolling stock in shunting or on collision occurring.

3. That a speed of 40 miles an hour can be run with ease and safety, as a speed of 35 miles an hour has been attained on the Festiniog Railway. The present working speed is 16 miles an hour, which I understand is about the standard speed for the proposed Indian lines on 5 ft. 6 in. gauge. Objections have been made to the accompanying plans of horse boxes and cattle trucks on four wheels, as not having the required stability, and danger

* Also for a general system of narrow-gauge railways in all countries.

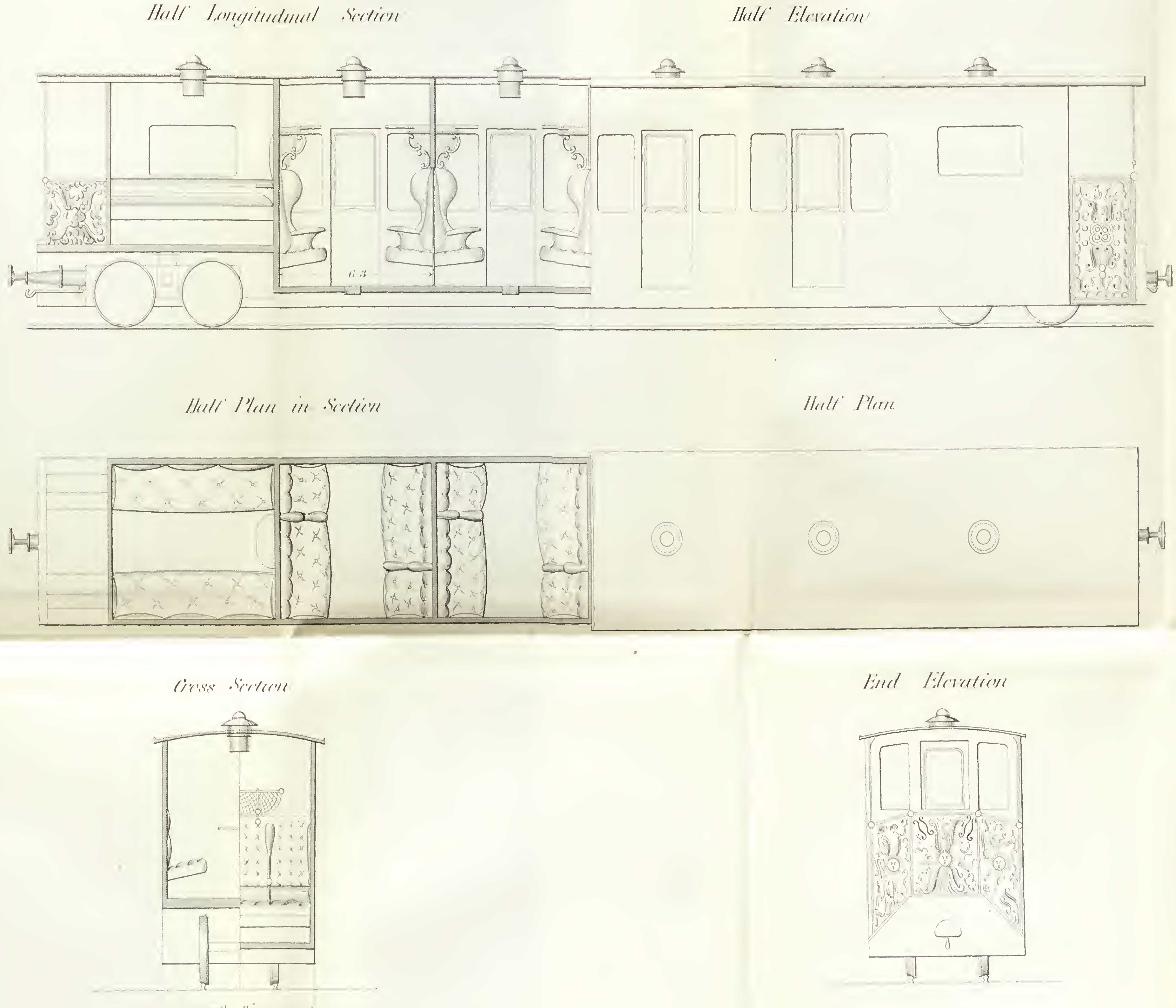
of their being blown over by the wind. The formula, however, by which this conclusion is arrived at, does not bear a practical test, as will be seen on comparing it with a Festiniog Railway carriage. This has a side area of 53 square feet; the centre of wind pressure is at 4 ft. above rail: the weight, when empty, $1\frac{1}{4}$ ton. The pressure of wind that it would balance, according to formula, would be $\frac{1 \cdot 25 \times 2240 \times \cdot 96}{53 \times 4} = 12 \cdot 6$ lbs. per square foot. They have, however, stood the severest storm known in this country without being blown off the rails at a time when large trees were rooted up. The amount of pressure necessary to blow a carriage over will also depend on the position of the centre of gravity. It is therefore evident that if these carriages with an angle of stability of 31° 31′ are quite safe, there can be no fear in regard to the stability of rolling stock on the 2 ft. 9 in. gauge, with an angle of 41° 30′. (See diagrams, page 84.)

4. As to the capacity of a 2 ft. 9 in. gauge to carry the required traffic. The Festiniog Railway proves that a very heavy traffic can be conducted; the capabilities of a 2 ft. 9 in. gauge in this respect are therefore evident.

To gain adhesion for the secured tractive power to transmit heavy trains at necessary speeds, and rolling stock of the required capacity, the most feasible known plan should be applied, *viz.* engines on the bogie principle, with four-wheel double bogie frames, or six-wheel double bogie frames, according to the gradients of the line or traffic; and, if need be, with lines of very exceptional gradients and heavy traffic, quadruple bogie engines, by which means the weight of engines is distributed evenly, and rolling stock dispersed over the line of way, flange and drag friction reduced to a minimum, saving in wear and tear of permanent way, great advantages gained in traversing curves, all of which means money saved in maintenance of way and rolling stock, besides of fuel consumed for a given load. The rolling stock can by this means be made to carry proportionately much more than the usual rolling stock on lines of the ordinary gauge. For instance, the bogie horse box weighs 7 tons, to carry six horses, with two compartments for grooms and fodder, having, when loaded, 1 ton 6 cwt. on each wheel, whereas an ordinary horse box on the 4 ft. $8\frac{1}{2}$ in. gauge weighs 6 tons, and carries three horses,

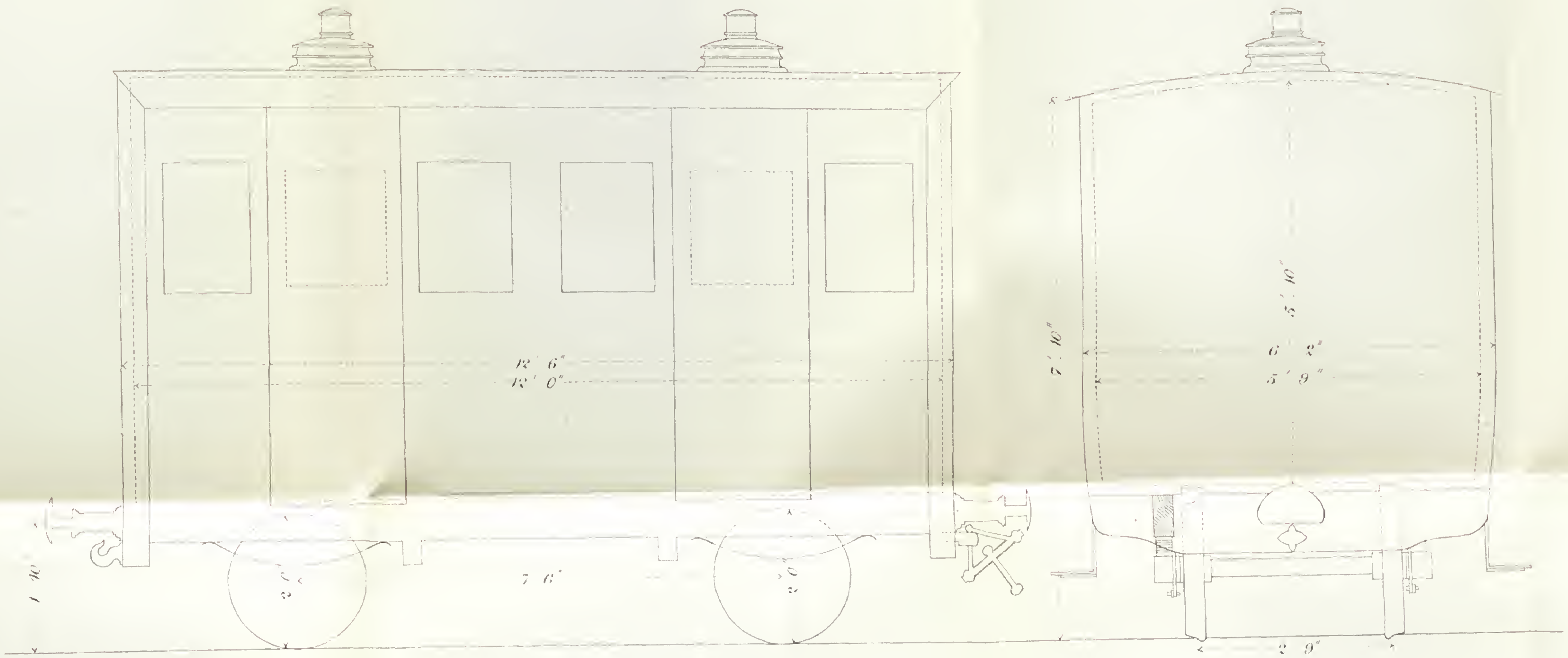
BOGIE PASSENGER CARRIAGE

For 2' , 9" Guage



PASSENGER CARRIAGE.

For 2' 9" Gauge.



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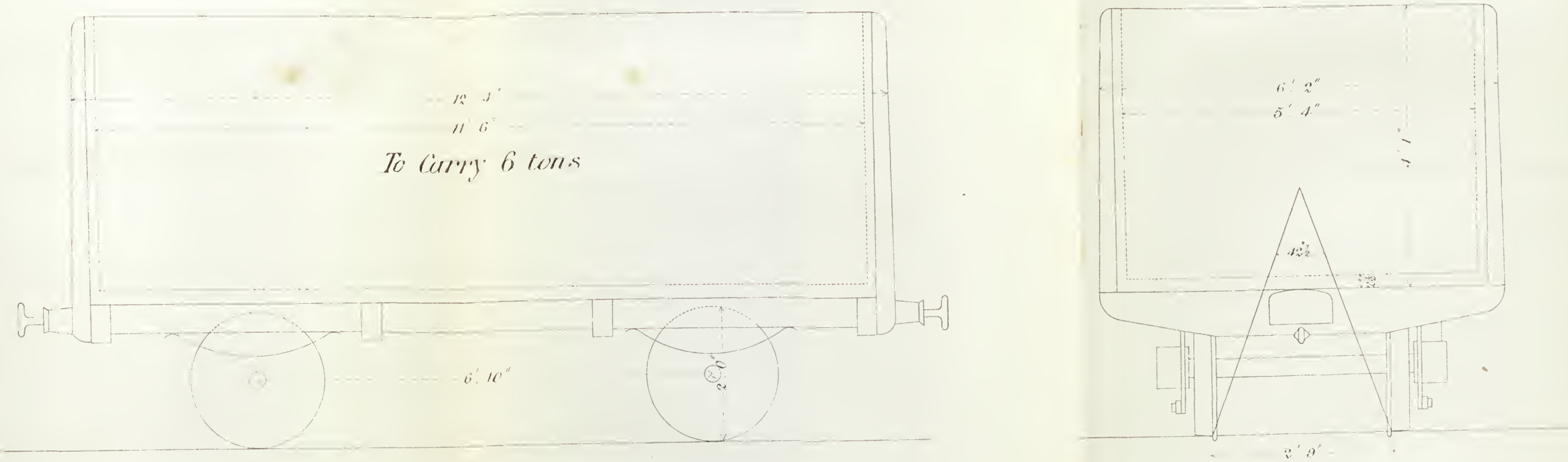
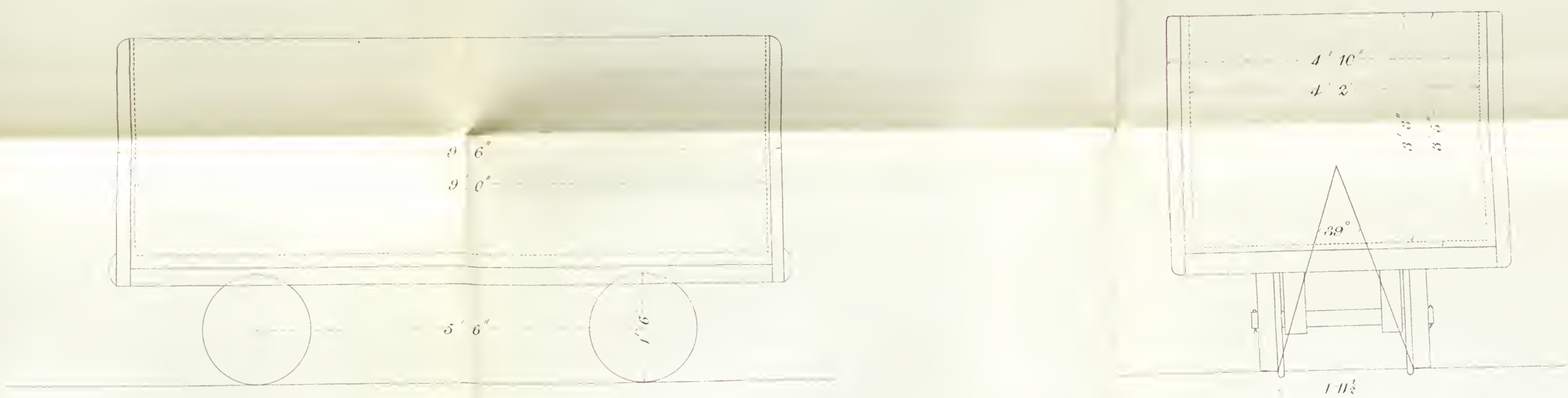
COAL TRUCK.

FOR 2' 9" GAUGE.



FESTINIOG RAILWAY COAL TRUCK.



WATERLOW & SONS, LITHOGRAPHERS, LONDON

with one compartment for groom, and having, when loaded, 1 ton 17½ cwt. on each wheel. The bogie cattle truck weighs 5 tons 15 cwt. to carry ten beasts, weighing, when loaded, 11 tons 15 cwt., or 1 ton 9 cwt. to a wheel. An ordinary cattle truck on the 4 ft. 8½ in. gauge, carrying ten beasts, weighs 5 tons 10 cwt., and, when loaded, 11 tons 10 cwt., or 2 tons 17 cwt. to each wheel. Surely these trucks, with low centre of gravity and steadiness secured with easy running on the rails, must have far greater stability and comfort to the beasts than those in use on the ordinary lines. Bogie trucks can be made for the 2 ft. 9 in. gauge of various dimensions and convenient sizes, for carriage of cotton, grain, and coffee, to hold from 30 to 40 bales of pressed cotton of 4 to 5 tons, and of grain from 10 to 15 tons; in fact, the bogie principle for this gauge affords a wide margin for construction of carriages and vehicles of any description and convenience. The accompanying plans of bogie passenger carriages are for first class, with van to carry thirty passengers, having seat room of 23 in. for each person; and third-class carriage, with van to carry fifty-six passengers, with seat room of 17¼ in. for each person. The four-wheel passenger carriage to carry twelve first-class or sixteen third-class passengers.

I advocate the bogie principle because I believe it to be practically the correct one, and which as a rule should form the majority of the rolling stock on narrow gauge lines, not but that bogie engines of one pair of cylinders for express passenger trains, and small four-wheel engines for shunting purposes should be applied, also small four-wheel trucks to any required extent in combination for light loads of minerals and goods. In the plan of bogie horse boxes all sagging is obviated by a sufficiently strong framing, nor is there any difficulty of arranging in the detail plans for the girder framing to resist the compressive and bending strains from the action of the buffers. On the Festiniog Railway trains of the four-wheel slate wagons are daily pushed or propelled over the Traethmawr embankment comprising 40 to 120 wagons without any sagging occurring. Horse boxes to carry many horses as well as few must have their advantages for horse dealers, and for military purposes. To obviate the possibility of a four-wheel horse box being overturned by wind pressure with single horse on the lee side of truck, there is no difficulty what-

ever in arranging the centre division of the stalls movable on rollers, and an auxiliary movable partition on one side, which can be used as necessity requires either for one or two horses. In respect to objections made to cattle trucks, it will appear impossible for the cattle to make escapades through the side openings, even though the cant-rail was made 2 or 3 in. higher, as their heads in rising would come in contact with the top rail or roof. Nor would there be any difficulty in putting the cattle into the truck from the low height of side, as the head would be well in before treading the floor level.

As regards the dimensions of the rolling stock on a line of railway, it is argued that the width ought to be double the gauge. This certainly approaches near to the width of what it should be. On the 1 ft. $11\frac{1}{2}$ in. the width of carriage having floor level above the top of wheels is $2\frac{1}{2}$ times, and on the 4 ft. $8\frac{1}{2}$ in. it is $1\frac{3}{4}$ times the gauge. The Festiniog Railway carriages and trucks run very steady at a speed of 20 miles an hour, and proved to have the lateral stability even when going over the old rails of 30 lbs. to the yard, unfished, when the joints were depressed on one side in many cases half an inch. There is no doubt that the rolling stock at present on the ordinary lines does not give nearly the proper carrying capacity compatible with the gauge. This cannot, however, be increased, as the weight already brought upon each wheel is too great, and the rails soon become disintegrated and crushed, lasting only four or five years under moderate traffic, and in cases of heavy traffic at or near stations only as many months. Steel rails for durability have great advantage, but at a heavier cost, though even these barely sustain the great weight and impact forces of the engines and rolling stock at high speeds; besides, steel against steel has the effect of sooner wearing out the tyres. I believe that the maximum weight on each wheel should not exceed 3 tons.

The trucks on ordinary lines having scarcely any overhang outside the framing, there is no counter-pressure against a collapsing tendency along the centre line of floor, but which would be the case when having a proper overhang.

5. In regard to the capacity of a 2 ft. 9 in. gauge for military purposes, it will be seen from the accompanying plan that heavy ordnance—say, two 12-ton guns—can be carried with the greatest

ease. The calculated weight is 5 tons 15 cwt., giving, when loaded, 2½ tons on a wheel. Trucks of this description would be available for carrying railway bars, bridge girders, &c. Field guns and other war material can be conveyed in the general goods trucks.

Portmadoc, Dec. 12, 1870.

THE BATTLE OF THE GAUGES.

Extract from 'The Engineer,' November 18, 1870.

"After an interval of nearly a quarter of a century, during which period the Indian Government have, with but slight deviation of purpose, adhered rigidly to the standard gauge of 5 ft. 6 in. originally determined upon for Indian railways, the pressing necessities of the country for further facilities of communication, and the smallness of its means to meet those requirements, has at length caused the question to be raised whether lines of a narrower gauge could not be constructed more expeditiously, and with greater regard to economy, than those already in existence in India. It is true that the present Oude and Rohilkund Railway system, originally started by the Indian Branch Railway Company, was to have been constructed on the 3 ft. 6 in. gauge. A light description of railway and a peculiar kind of locomotive had been adopted by this company, but the consideration of their suitability for the purpose was submitted to a committee consisting of Colonel R. Strachey, R.E., and other royal and civil engineers. The result is that the whole system in Oude and Rohilkund is being constructed of the standard Indian gauge. The Indian Tramway Company's line from Arconum to Conjavaram in the Madras Presidency, now known as the Carnatic Railway, was actually constructed with a gauge of only 3 ft. 6 in., but quite recently the Secretary of State for India has entered into a contract with the company for the conversion of their light narrow gauge railway into a 5 ft. 6 in. line, and for extending it to Cuddalore. So much for the existing guaranteed lines, all of which are now constructed upon the broad Indian gauge. With the exception of the little branch from Jhellum to Khamgaon, which has also been constructed upon the standard gauge, the proposed State lines are at present at a standstill.

"A lavish expenditure has for many years past been going on in the construction of magnificent lines of railway, with many of their accessories planned upon the same scale of grandeur; and just as the Indian Government is about to launch out into a rapid

extension of the existing system of railways, and to add 10,000 miles of line to the 5000 already constructed, or under construction, a sudden pause is made, Government reconsider their determination, and like a large landowner who has for some time been exceeding his available means in the improvement of his estate, they begin to inquire whether the works yet remaining to be done cannot be undertaken upon a scale less grand, yet equally suitable for all present requirements, the cost of which can fairly be defrayed out of the revenues of the estate. Fortuitously, just at this moment, when through some error of accounts a serious deficit is apprehended in the year's revenues, the two principal advisers of the Supreme Government of India, in questions relating to public works, happen to be in this country, a committee is formed of which these two officers are elected members, to consider the great question to which we have already referred. These two officers were none other than Colonel Dickens, Secretary to the Government of India in the Public Works Department, and Colonel Strachey, the officiating secretary in the same department. Anyone who knew the force of character of the last-named officer, and was acquainted with his position in the committee which took into consideration the proposed scale of works for the Oude and Rohilkund lines, and the ultimate results of the labours of that committee, would at once have concluded—and with perfect justice—that, even if any deviation from the existing gauge were recommended, it would be but trifling, and that probably economy would be enjoined more in the construction of stations and in the weight of engines and permanent way than by any diminution of gauge.

"*Nemo mortali um omnibus horis sapit!* and it is indeed impossible for anyone to say how soon he himself—and much less how soon anybody else—may change his opinions, and in effect condemn what he has previously recommended. Our readers are already aware of the result of the Indian Gauge Committee's report; how that a difference of opinion prevailed, and that whilst Mr. J. Fowler recommended a 3 ft. 6 in. gauge for the future of Indian lines, with certain exceptions where he proposed they should be constructed of the standard gauge, but in a cheaper manner, and with lighter permanent way, the remainder of the committee, including Colonels Strachey and Dickens, went so far as to prefer a gauge

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of only 2 ft. 9 in. It is not difficult to predict which of the two reports will be likely to be accepted by the Government of India, with whom it is presumed the determination of this, as of all other technical matters relating to public works, will be permitted to rest. Without in any way reflecting upon the honour of any of the gentlemen concerned, it is but reasonable to suppose that if Mr. Fowler or any other member of the committee could place himself at the right hand of the Governor-General and his council in India, during the time when the reports together came under their consideration, that one who could personally urge the special merits of the gauge recommended by him, would stand the best chance of turning the opinion of the Executive in favour of that gauge ; and each would most probably be fully prepared to point out weak points in the other's recommendations. Now, it so happens that Colonel Strachey is on his way out to India, and he will soon be followed by Colonel Dickens. Each in his capacity as secretary to the Government of India in the Public Works Department would most probably have to advise the Government upon this very point, Colonel Strachey in the absence of Colonel Dickens, and the latter officer upon his arrival back at Calcutta, upon which event it is reported that Colonel Strachey is to be appointed to a new department as Minister of Agriculture. Now, if either of these officers has to advise Government upon a point he has already pledged himself to in a previous report, it is but reasonable that he should make his recommendations in accordance with his previously-expressed opinions. Anticipating, in some measure, the final settlement of this question, we shall now proceed to consider the respective merits of the two gauges recommended for India, and in doing this it is necessary, not only to take into account all that might be said for and against each of the two gauges proposed by the committee with reference to their individual merits, but also with regard to all the circumstances of the present case, and especially to the exceptional character and peculiarities of the country for which they are intended to be adopted.

"It may be laid down as a general principle in railway construction that with equal weights and equal speed of trains, all the important items are constant. Any difference in gauge will but slightly affect the question of cost, inasmuch as the principal

points regulated by the gauge are the width of the formation level and the length and section of sleepers where they are laid transversely. Sir John Lawrence in 1869, when Governor-General, stated that, in the construction of new railways in India, the necessity of keeping down the first cost, so far as that could be done consistently with the probable requirements of traffic and the soundness of the works, should ever be kept in view as the great primary point of consideration. At the same time he pointed out that, if this essential condition could be better secured by adopting a narrower gauge and a lighter style of permanent way and rolling stock, such change should be accepted. The consequences of any change of gauge, with its attendant inconveniences as affecting traffic, by necessitating change from one set of trucks and carriages to others, must of necessity be the same, whatever may be the new width of gauge adopted; and although such change cannot but involve a certain additional charge upon freight in the matter of goods, that question came fairly under the consideration of the Supreme Government last year, and it was then thought that the lesser difficulties which break of gauge might involve in traffic management would be an incomparable smaller evil than the unnecessary expenditure of many millions of money. Upon these and other considerations, amongst which may be stated the urgent demand for a considerably increased extension of railway communication in India, the adoption of a narrower gauge and cheaper construction has been determined upon. Nothing, however, would be more unreasonable than that all new lines should be made on the new gauge, whatever they may be, for there are certain projected railways which could not, without serious inconvenience and probable danger, be constructed upon any other than the present standard gauge, which, we hold, must be maintained for the great arterial lines of communication throughout the country, and those of primary importance from a political or military point of view—such, for instance, as the proposed extension of the Punjab line as a State railway from Lahore to the extreme north-west frontier at Peshawur, and the 'missing link,' or Indus Valley line between Kotree and Moultan. Other projected lines might, perhaps, also be mentioned where the retention of the present gauge would be desirable, but in no case could it be more important than in that of the two lines named above, which,

from their military and political importance, are second to none in the whole of India. Whether these lines should be laid with a lighter permanent way than has hitherto been adopted is a question quite apart from that of gauge, and which should be made to depend, not upon the same question as that which must determine the best gauge, but upon the probable requirements of the country traversed as regards capabilities of traffic, and the greatest amount of goods to be transported over the line. If the probable maximum traffic be such only that a lighter class of locomotive will suffice for its haulage, then it would be adverse to all considerations of economy to adopt the heavier engines, which would also necessitate a more expensive permanent way. From the foregoing considerations may be deduced the following axiom, namely, that the gauge and weight of permanent way of Indian lines henceforth to be constructed depend respectively upon their military or political and their commercial importance. It is possible that, in some instances, projected lines will be found to be of great importance from both points of view, in which case—supposing, of course, that they would either be at once connected with, or ultimately form part of, the existing system of trunk lines—it would obviously be unwise to depart from the standard principles adopted in existing lines; whilst, on the other hand, where a line is simply required in order to open out a hitherto undeveloped district, the narrower gauge and lighter form of construction may advantageously be combined.

"The construction of two classes of roads has long been in practice in India, all 'first-class' lines being metalled and bridged throughout, and so made passable for carts during the whole year, whilst 'fair weather' roads are only available duing the dry season. Similarly, the same rule may, with economy, be applied to railways, in which case all trunk lines should be of the standard gauge, whilst strictly branch or other lines of secondary importance might be constructed upon a narrower gauge. By all means, however, a multiplicity of gauges should be avoided, and one standard only should be authorized for first-class lines, and another standard for such as might not be considered of sufficient importance for so expensive a style of construction. The gauge of trunk lines being already determined by that adopted in the case of those now in existence, it remains now to consider whether a gauge of 3 ft. 6 in.

or one of 2 ft. 9 in. would be the better suited for India for her secondary system of railways.

"One great point of consideration with regard to these secondary lines is that many of those most urgently required, such as between Carwar and Dharwar; the extension of the Bombay and Baroda line, *viâ* Neernuch, to Delhi; and the proposed railway from Indore to Malwa, all have to pass through hilly districts where any difference of gauge would tell immensely upon the total cost of the works, and that to such an extent as to make all the difference between their being remunerative or ruinous undertakings. In opposition to a formerly accepted belief in the immense wealth of India, it has—especially in recent years—been discovered that India really is very poor. We will not now stop to inquire whether this is owing to maladministration; but it must be apparent to anyone who has taken the trouble to interest himself in the welfare of that country that its financial position does not improve as it should, and that increased annual revenue is usually more than counterbalanced by an increase of charges. The revenue derived from opium has always constituted a large portion of the country's income. Of late years this has fluctuated largely, and fears have been expressed in well-informed circles that no great reliance can be placed upon it for the future. Under these circumstances, and from the consequent necessity of developing the full natural resources of India as rapidly as possible, so as to open out other sources of revenue against the apprehended failure of that from opium, it is of paramount importance that railways should be rapidly constructed in various directions, and at the least possible cost consistent with good workmanship. Advocates of broad gauges have at times gone rather out of their way to prove the smallness of saving that can be effected by any reduction in the width of the gauge; but in a country like India it is not too much to say that saving in first cost should be effected at the expense of everything except that of efficiency. As, therefore, it is not denied that a diminution of gauge is attended with a reduction of first cost, it follows that the best gauge for India will be the narrowest that can provide efficient accommodation for the greatest amount of traffic that is likely to be brought upon it. It would, of course, be impossible to estimate the probable amount of traffic on any Indian railways from which to deduce arguments in favour of one

gauge or another for any particular line ; some useful information on the subject, however, may be obtained from statistics of the actual traffic on existing railways contained in Mr. Danvers' report for 1869–70. Taking the East Indian Railway as that upon which the largest amount of traffic is carried, and debiting all the minerals and merchandise carried to the goods and mineral trains, leaving out the mixed trains by which a large goods traffic was no doubt carried, we find that during the year 1,205,730 tons of minerals and merchandise were carried in 16,504 trains, travelling an aggregate distance of 3,282,472 miles. This would give 73 tons only as the average load of each train. Supposing the trucks and wagons to have weighed two-thirds as much as the live or paying load, the trains would then have averaged 126 tons each, exclusive of the engine ; certainly by no means an excessive weight of train for a 5 ft. 6 in. gauge line, with its heavy, powerful engines. If, however, a reduction be made in the average weight, by taking into consideration the mixed trains, which amounted during the year to 15,050 in number, or within about 1500 of the number of goods and mineral trains, it is not probable that the average weight would have exceeded 100 tons each. This, it must be borne in mind, represents the traffic on the line of railway which must always be the most important one, in respect of traffic, in the whole of India. Out of a total goods traffic of 3,341,908 tons, however, the East Indian and Great Indian Peninsula Railways carried 2,203,473 tons, or about two-thirds of the whole, whereas their aggregate mileage is but little more than half that of the total length open in India. Under these circumstances it can hardly be said that a 2 ft. 9 in. gauge would be too narrow for the probable requirements of secondary lines of railway in India.

"Next, as regards cost, a great deal has been said upon this subject, and estimates have actually been prepared for one of the proposed new lines—namely, that from Carwar to Hooblee—for the respective gauges of 5 ft. 6 in. and 3 ft. 6 in., from which we may calculate the probable difference that would be made by reducing the gauge to 2 ft. 9 in. In these estimates 3000 cubic yards of earthwork per mile is given as the difference between the 5 ft. 6 in. and 3 ft. 6 in. gauges with deep embankments, where they aggregate 59,000 and 56,000 cubic yards respectively. At this rate the difference between the broader gauge and one of

2 ft. 9 in. would be just 4000 cubic yards, which, at nine annas per yard, would show a difference of 2250 rupees, or 225*l.* per mile in favour of the 2 ft. 9 in. gauge in the matter of earthworks. It would clearly be much more in favour of the narrow gauge in rockwork and tunnelling. Mr. Hawkshaw has estimated that the saving of capital outlay which would accrue from the adoption of the 3 ft. 6 in. gauge instead of the 5 ft. 6 in. gauge would amount to 2800*l.* per mile; and at the same rate of difference 924*l.* a mile more would be saved by the still further reduction of the breadth of gauge to 2 ft. 9 in. Now, it is roughly stated that some 10,000 miles of new railways are required in India, of which, probably, not less than 7000 are of secondary importance, and 3000 such as should form part of the great trunk system of railways. Knowing, as we do, the fallacy of almost all estimates relating to India, and the constant fluctuation of rates of work, and their difference in various localities, it is not our intention to speculate for what amount lines might be made upon the different gauges; suffice it here to observe that if one of 2 ft. 9 in. gauge can be constructed for 200*l.* a mile less than one of 3 ft. 6 in., the narrow gauge ought certainly to be adopted, representing, as it would, a saving on the whole 7000 miles of little less than one million and a-half sterling, or sufficient to construct 100 miles of broad first-class lines, and probably nearly double that amount of branch or secondary lines. The annual interest upon the sum thus saved, at 5 per cent., would amount to no less than 70,000*l.*, an amount which the Indian Government cannot afford to throw away for an idea.

"If, then, as we have no reason to doubt will prove to be the case, it cannot be shown that upon any of the proposed lines a 2 ft. 9 in. gauge would be incapable of carrying all the probable traffic for many years to come, no arguments could justify the adoption of a broader, and consequently a more expensive line; whilst if, on the other hand, the anticipated requirements prove likely to be in excess of what could be provided by such a railway, then it is most probable that such a line would be of sufficient importance to take part in the broader system of trunk railways, and should be constructed of the existing standard gauge, and with light or heavy permanent way, as circumstances may seem to require."

INDIAN RAILWAY GAUGES AND ROLLING STOCK.

Extract from 'The Engineer,' December 2, 1870.

No. 1.

"We fully intended to have followed up the subject of our article headed 'The Battle of the Gauges,' in last week's number of 'The Engineer,' but were subsequently induced to delay doing so until now, owing to our inability to complete certain statistical information which, it will be found, bears very strongly upon the questions under consideration. In the meanwhile several points in our former article have been commented upon, in a somewhat unscrupulous manner, by a contemporary, who charges us with making statements which it will be found by a careful reader we especially repudiated, and draws absurd conclusions from paragraphs quoted without their contexts. It would be mere waste of time to reply to the several assertions thus made *seriatim;* but the following remarks will no doubt fully establish the fact that our preference of the 2 ft. 9 in. gauge to one of 3 ft. 6 in. for lines of secondary importance in India was based upon reliable and substantial grounds. It must, however, be observed that in drawing comparisons between these two gauges we in no way wish it to be concluded that we consider one of 2 ft. 9 in. the best that could be adopted for India, although it certainly possesses advantages, as we shall presently show, that would be unattainable by any broader gauge. But before proceeding farther with our subject we feel that in justice to our readers, as well as to ourselves, some few words are necessary in reply to the charge which has been made against us of having ranged ourselves upon the stronger side. Such a remark is evidently intended as a direct charge of dishonesty, which it is almost needless to repudiate. If the majority of the committee should be stronger in influence as well as in numbers, it must also be borne in mind that its members have all been for many years intimately connected with Indian railways, whilst the single member constituting the minority has not had similar advantages in that respect. The former, it may naturally be expected, know well what the real requirements of India are with regard to communications, and it

is not an insignificant fact, or one that should be overlooked, that all those members of the committee who possessed any actual experience of India, and the working of Indian railways, should have agreed together on this subject of gauge. Although the same recorded information was no doubt available to all the members of the committee, the majority must have possessed a vast amount of knowledge, gathered from their own individual experiences, which could not be imparted in the same manner as that which was published; the single member of the minority must therefore, in a great measure, have based his conclusions more upon his own personal experience of the railway necessities of other countries than upon his knowledge of Indian requirements.

"Even at the present time India is but half developed, and it would be unreasonable to lay down a vast system of railways, such as is in contemplation, upon a scale commensurate with the circumstances of any European country. Indeed, it may be concluded that the carrying capacity of a railway on any gauge which will satisfy the conditions of safety and convenience will, for a very lengthened period, be in excess of the requirements of the traffic likely to be brought upon the projected extensions of railways in India for which a narrow gauge is contemplated. Therefore, to obtain the greatest economy in construction, and consequently the greatest possible extension of railways in India, the gauge selected should not only be narrow, but the narrowest which will combine convenience of transport for various kinds of goods and passengers with reasonable speed, and with economy and safety in working. As it would obviously be inconvenient to have more than two gauges, the necessities of the country traversed by each proposed new line must, as we pointed out the week before last, determine whether it should be constructed upon the existing standard gauge of 5 ft. 6 in., or upon the new narrow standard which is to be introduced. The opponents of narrow gauges generally make a strong point of their unsuitableness for the conveyance of horses and guns for military service, and the same argument is now taken up against the 2 ft. 9 in. gauge by the advocates of the 3 ft. 6 in. standard; and no doubt, neither is so well adapted for that kind of traffic as are railways laid with a broader gauge. Mr. C. E. Spooner, of Portmadoc, has, however,

recently shown how horse boxes to carry six animals may be adapted for a line of 2 ft. 9 in. With regard to the transport of field guns, also, there would not appear to exist any real difficulties in the case, although it is indisputable that their conveyance could be more conveniently accomplished upon a moderately broad than upon a very narrow line of railway; on the latter, however, they could always be conveyed in ordinary goods wagons when detached from their carriages, and the conveyance of men and material could be as easily effected on lines of 2 ft. 9 in. as on those of 3 ft. 6 in. As to the necessity for providing the means of conveying guns upon these secondary lines of railway, it must be remarked that but few of them are likely to traverse districts where military operations will probably be necessary, and it would obviously be far more unreasonable to construct lines upon a wider gauge than was required for ordinary purposes of traffic, in order that the ordinary goods wagons might be capable of carrying guns upon an improbable contingency, than that each line should be provided with a certain number of trucks specially designed for that purpose, even though they could not be employed for the general traffic of the line, which is unlikely. With regard to the possible need for the narrow lines of India to fulfil military requirements, it will hardly escape the notice of the most casual observer who knows anything about India, that such lines will be required mostly in the Peninsula and Central India, where the inhabitants are peaceful and industrious; whereas the North-West Provinces and the Punjab, where disturbances do sometimes occur, and whence any attack from without, should it ever take place, may be expected, are already well supplied with first-class broad gauge lines of railway; and we maintain that, on account of their military importance, the Indus Valley line, and the line from Lahore to Peshawur, should be constructed of the same width.

"Economy in first construction of these secondary lines of communication in India also will not fail to prove of importance from a political point of view. The more rapidly and extensively railways can be constructed throughout the empire, the greater will be the hold of its present Government, and the sooner will the influence of British rule be felt in its remotest districts; tending at the same time to encourage industries, neutralize the effects of famine, and break down caste; also, by the example thus set,

native rulers will—as they have already commenced to do—by introducing railways into their own states, all the sooner bring to bear similar influences upon their own people. This is entirely a question of cost; and, with a fixed standard of excellency of construction, cost is a question of gauge, the limit of which must of course be dependent upon considerations of efficiency.

"As long ago as the year 1867 the attention of the Indian Government was drawn to the unfavourable ratio that generally existed between the dead weight and paying loads of wagon stock on Indian railways, which must always occur when an undeveloped country is provided with broad gauge railways, and to the importance of taking measures for increasing the carrying capacity of the vehicles. Communications on the subject were accordingly addressed to the agents of the several railway companies in India, from whom some very valuable information was collected. The general result appears to have been that want of strength, and not want of capacity, was the principal defect. Moreover, the wagon stock, having been built after the English pattern, has proved quite unsuited to the character of the bulk of goods carried on Indian railways, and this is an important fact in connection with our present question. Mr. Cecil Stephenson, deputy agent, East India Railway, pointed out that out of fifty-eight articles of general traffic, seven only were too bulky to complete the full load of the smaller class of wagons used on the line, and five only of the larger class; and that unless the wheels and axles of their stock could be made to carry 12 tons it would be impossible properly to utilize them, even with their existing dimensions, for the bulk of the traffic on the line. From a table given in the correspondence upon this subject it appears that four classes of wagons on the East Indian Railway, weighing 6 tons each, were only capable of being loaded up to 6 tons, whilst two other classes were calculated to carry 10 tons. The largest traffic on that railway is in the following articles, *viz.* coal, ironmongery, piece goods, salt, wines, grain, rice, seeds, cotton; and as the cubical measurement of goods in India must have a very considerable effect in determining the commercial value of rolling stock on different gauges, we give below some particulars drawn up with reference to the carrying capacity of the largest and smallest of the ordinary 6-ton goods wagons on the East Indian lines.

Weight which could be put in Smaller Wagon if strong enough.	Nature of Materials.	Cubic feet to the ton of 20 cwt.	Cubic Space occupied in a Wagon limited to 6 tons Weight.	Waste Space in each Wagon.		Space required to complete Full Load of 6 tons in Wagon.	
				Measuring 644 cubic feet.	Measuring 720 cubic feet.	Measuring 644 cubic feet.	Measuring 720 cubic feet.
tons.							
215	Lead	3	18	626	702		
161	Copper and Brass ..	4	24	620	696		
143	Spelter	4½	27	617	693		
135	Wrought iron	4¾	28	616	692		
129	Cast iron and zinc ..	5	30	614	690		
49	Granite	13	78	566	642		
26	Sand	25	150	494	570		
24	Slates	27	162	482	558		
21	Bricks..	30	180	464	540		
19	Saltpetre	34	204	440	516		
18	Sal wood	35	210	434	510		
15	Rye and sugar	41	246	398	474		
15	Borax	42	252	392	468		
15	Salt	43	258	386	462		
14½	Rice, peas, dall, beans	44	264	380	456		
14	Deodar	45	270	374	450		
14	Wheat and tallow ..	46	276	368	444		
14	Grain	47	282	362	438		
13½	Beer or wine in bottle, and coals	48	288	354	432		
13	Flour	50	300	344	420		
12½	Teak	51	306	338	414		
12	Oats and mustard seed	53	318	324	402		
12	Spirits in wood and linseed	54	324	320	396		
11½	Barley	55	330	314	390		
11	Coffee and paddy ..	56	336	308	384		
11	Safflower	58	348	296	372		
9	Turmeric	71	426	218	294		
8½	Tilseed	73	438	206	282		
8½	Cotton, full screwed ..	75	450	194	270		
8½	Shellac and lac dye ..	77	462	182	258		
8	Pepper	81	486	158	234		
7½	Ginger and hides ..	84	504	140	216		
7	Jute and cotton, screwed to 24 lbs. ..	93	558	86	162		
6½	Bran	98	588	56	132		
6	Indigo in chests ..	107	642	2	78		
5¾	Leather and charcoal	112	672	..	48	28	
5½	Coriander seed and tea	119	714	..	6	70	
5	Shellac	127	762	..	..	118	42
4½	Firewood	140	840	..	..	196	120
4¼	Sheepskins in bales ..	149	894	..	..	250	174
3½	Cork	194	1154	..	..	516	444
3	Chillies (dried)	213	1278	..	..	634	558

"Having thus ascertained the cubic measurement per ton of the principal articles of Indian commerce, we have next to draw comparison between the weight and capacity of rolling stock upon

various lines of railway having a gauge not greater than that of the Indian standard. Before doing so, however, we may supplement the foregoing statement with other particulars and the dimensions of cotton bales as they are received in this country from India. They are, of course, what are termed as 'full screwed,' and their weights, as furnished to us by some leading cotton brokers of London, do not materially differ from what is given above. The dimensions of these bales are 3 ft. 6 in. high by 1 ft. 6 in. deep, and 1 ft. 10 in. broad. As upon some of the proposed new lines cotton will constitute the principal article of traffic, the size of the bales must exercise a very important influence upon the proportions of the trucks to be employed in their transport. Upon this subject we shall have more to say farther on. One very important point cannot fail to become apparent from a study of the particulars given above, and that is, how immensely out of all proportion to the economical performance of their duties the existing Indian goods wagons have proved to be. This will be still more apparent upon examination of the following table.

"In this table we have given only representative rolling stock on lines of the different gauges named, as it would clearly be unnecessary for our present purpose to multiply the evidence thus afforded of the capacity of the different rolling stock on other lines. By comparing the results thus obtained with the particulars given in the preceding statement relative to the principal items of goods traffic in India, some estimate may be arrived at as to the carrying capacity really required for individual wagons on Indian railways. Now, it will at once appear that even the low-sided open wagon of the Queensland Railway would be too capacious for the economical conveyance of the first six materials named in the list. Supposing the load limited to 4 tons per wagon, which would be equal to a maximum weight of about 1½ ton per wheel, the dimensions of the wagons for conveying those articles need not exceed 10 ft. 6 in. in length by 5 ft. wide and 1 ft. height of side internal measurement. The 26 following articles, exclusive of timber, would require wagons 21 ft. long by 5 ft. wide, and 3 ft. 9 in. high, which should be on six wheels, and the remaining articles could be provided for by covered vans of an increased length, carried upon bogies. Now,

Name of Railway.	Class of Vehicle.	Dimensions of Body inside. Length.		Width.		Height at the Centre.		Height at the Side.		Area of the Floor.		Cubical Contents.		Number of Wheels.	Length of Journals.	Diam. of Journals.	Product of the Length by the diam.	Total Weight when Empty.	
		ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.		in.	in.	in.	t.	c.
5 ft. 6 in. gauge:—																			
Great Indian Peninsula ..	Low sided—open	18	7	8	1	1	2½	1	2½	150	3	..		4	9	3¼	29¼	5	17
		18	7	8	1	2	0	2	0	150	3	..		4	9	3½	31½	5	18
		16	8	8	1	1	2½	1	2½	134	8	..		4	9	3¼	29¼	5	3
	Covered	16	6	7	8	6	6	5	3	124	6	736	7	4	9	3½	31½	5	17
		16	6	7	8	6	6	5	3	124	6	736	7	4	9	3¼	29¼	5	15
	Cotton van	23	6	9	0	8	0	6	8	211	6	1551	0	4	9	3½	31½	6	14
		19	6	9	0	8	0	6	8	175	6	1287	0	4	9	3¼	29¼	6	5
	High sided—open	16	8	7	8	4	11	3	1½	127	9	521	8	4	9	3½	31½	5	8
		16	8	7	8	4	11	3	1½	127	9	521	8	4	9	3¼	29¼	5	14
Ceylon	Low sided—open	15	7	7	9	1	1	1	1	120	9	..		4	9	3¼	29¼	4	14
	Covered	15	5	7	7	6	3	5	10	117	0	711	9	4	9	3¼	29¼	6	5
		14	5	7	7	6	3	5	10	109	4	665	1	4	9	3¼	29¼	6	3
	High sided—open	15	7	7	9	2	11½	2	11½	120	9	357	1	4	9	3¼	29¼	5	5
Santiago and Valparaiso ..	Low sided—open	15	7	8	1	2	4	2	4	126	0	..		4	8	3½	28	5	8
	Covered	15	4	7	9	8	0	7	2	118	10	901	1	4	8	3½	28	6	15
5 ft. 3 in.:—																			
Irish	Covered	13	3	7	3	6	10	5	1	96	1	576	6	4	6	3	18	5	10
		15	0	7	6	6	10	5	1	112	6	675	0	4	6	3¼	19½	5	18
		13	4	7	3	6	10	5	0	96	8	572	0	4	8	3	24	5	15
	High sided—open	13	8	7	2	3	3	2	9	98	0	294	0	4	6	3	18	5	0
5 ft.:—																			
Russian	Covered	20	10	8	5	7	10	7	4	175	4	1329	7	4	6½	3½	23	5	15
		20	7	8	7	7	4	6	11½	176	8	1266	1	4	6¼	3½	21⅞	6	15
	High sided—open	20	8	8	8	5	8	3	3½	179	1	805	10	4	6¼	3½	21⅞	5	5
4 ft. 8½ in.:—																			
London and North-Western	Low sided—open	15	0	7	1½	0	9	0	9	107	0	..		4	6	3	18	3	15
		15	0	7	1½	1	8	1	8	107	0	..		4	6	3	18	4	0
		15	1	7	2	0	8½	0	8½	108	1	..		4	6	3	18	4	1
		15	1	7	2	1	9	1	9	108	1	..		4	6	3	18	4	2
		15	0	7	2	1	10	1	10	107	6	..		4	6	3	18	4	4
	Covered	12	10	6	6	6	2	5	6	83	5	486	9	4	6	3	18	4	10
		15	4	6	10	6	2	5	6	104	9	611	0	4	6	3	18	5	1
3 ft. 6 in.:—																			
Queensland	Low sided—open	19	6	6	0	2	6	2	6	117	0	..		4	6¾	3	20¼		
	Covered	19	6	5	11	6	0	5	0	115	4	634	6	4	6¾	3	20¼		
		29	0	5	11	6	0	5	0	171	6	943	9	6	6¾	3	20¼		

5 ft. internal measurement is by no means in excess of the width that can safely be given to wagons on a 2 ft. 9 in. gauge, neither would it be too narrow for rolling stock on a 3 ft. 6 in. gauge; but it may be argued, if the traffic required to be provided for can thus be carried upon lines of the narrow gauge with safety and moderate dispatch, of what advantage to such traffic would it be to provide lines of a broader gauge? With regard to the question of dispatch, it is presumed that the light railways of India will be in some measure subjected to the regulations contained in clause 28 of 31 and 32 Vict., cap. 119, wherein it is laid down that on light railways 'the weight of locomotive engines, carriages, and vehicles to be used on such railway shall not exceed 8 tons to be brought upon the rails by any one pair of wheels; and the rate of speed shall not exceed at any time 25 miles an hour.' With regard to the capabilities of a 2 ft. 9 in. railway for such a speed, as well as to the safety of so narrow a gauge, we possess abundant proof in the working experiences of the Festiniog Railway. Since many of the new lines will be largely employed in the conveyance of cotton, the capabilities of the rolling stock for conveying screwed bales of cotton to the best advantage is by no means an unimportant subject for consideration; and it will be found upon measurement that a truck 5 ft. wide and 21 ft. long would conveniently convey thirty bales, without any waste, and weighing as nearly as possible 4 tons."

No. II.

"Having already considered the practical part of the question as to whether a railway having a gauge of 2 ft. 9 in. could be constructed to convey the mineral and goods traffic in India, we have yet to see to what extent such lines would be capable of bearing any considerable development of such traffic. In order to ascertain this it will be necessary to take into consideration what amount of goods traffic could be conveyed upon such a line as that proposed by Messrs. Strachey, Dickens, and Rendel, and whether it would be likely to suffice for the requirements of India for such a length of time as would fairly justify the adoption of a gauge narrower by some inches than has hitherto been

adopted as a standard gauge in any other country. Fortunately, the statistical facts published annually by Parliament, with reference to the points of most importance in the consideration of this question, are such as to enable us to draw some reliable comparison with other countries on these important points, and it is only by such comparisons that the real question at issue can be satisfactorily determined. At best, perhaps, the facts from which we can draw our conclusions may not be considered altogether satisfactory, but it is only by comparing the commercial requirements of different nations, and the means found sufficient for meeting them, that any conclusions can be drawn as to the necessities of other countries still to be provided with railway communications. It is not necessary to go much out of the way in order to prove that, as far as goods traffic is concerned, something even less than 2 ft. 9 in. would amply satisfy the present requirements of India. Probably no one has ever before thought to compare, in the following manner, the relative duties of the whole railway system in India with that actually performed by the little Festiniog Railway, but the results certainly are startling, and cannot be wholly explained away by the fact that the latter is a line of railway having a peculiar traffic of its own, and is placed under such circumstances that it can be made to perform a maximum amount of work, and is not so much dependent upon the fluctuations of trade and other circumstances as are most railways. It must, however, be borne in mind, on comparing the results shown in the following table, that the particulars relative to India do not represent an average of all the lines, but a gross total of their performances; but the receipts of the East Indian and of the Great Indian Peninsula lines for goods traffic during the year 1869 amounted to 76 per cent. of the whole of the Indian lines, whilst their lengths combined amount only to a trifle less than 55 per cent. of the entire Indian system. Some relative estimate may therefore be drawn as to the probable traffic of the remaining lines. At any rate, the following statistics will show clearly, so far as goods traffic is concerned, how far the proposed gauge of 2 ft. 9 in. would be likely to be too narrow, or otherwise, for the probable requirements of India for the secondary system of communications with which it is proposed now to furnish her:—

Railway.	Total Length.	Train Mileage in 1869.	Total Weight of Goods Hauled.	Weight of Goods Hauled per mile per annum.	Weight of Goods Hauled per Train mile.
	miles.	miles.	tons.	tons.	tons.
Festiniog	14	50,314	136,132	9388·41	2·7
Indian Lines	406·5	10,093,412	3,341,908	822	0·33

"From this it is shown that the little Festiniog line, of 1 ft. 11½ in. gauge, actually had conveyed over it upwards of eleven times the weight of goods per mile per annum, in 1869, that was hauled over the Indian lines of 5 ft. 6 in. gauge, whilst the weight of goods hauled per train mile during the same period was eight times as much on the former as upon the latter lines.

"Nothing shows so much the real position of a country as a comparison of its wealth and population with those of other nations; we shall, therefore, endeavour to show the position of India in these respects as compared with other countries, as upon the result of such comparison may be, in some measure, calculated how far her requirements can justify a lavish expenditure upon railways; and, taken in conjunction with facts previously ascertained, the following particulars will probably go far towards justifying our former remark, that the least possible expenditure should be now incurred in the construction of future railways, of a class not superior to what is likely to prove sufficient for the requirements of the country for some years to come. In this calculation we have added statistics regarding other European countries, including Sweden, where a system of 3 ft. 6 in. railways is now being introduced, which will make the comparison of more value than if it had been confined merely to England and India.

	Area in Square Miles.	Population.	Population per Square Mile.	Total Trade.	Trade per Head of Population.		
				£.	£	s.	d.
Great Britain and Ireland	122,152	30,621,431	242·5	532,535,292	17	6	3
France	209,352	38,192,694	182·43	293,144,000	7	13	6
Italy	112,737	26,227,915	232·65	67,302,317	2	11	4
Sweden	170,621	4,173,680	24·45	10,447,802	2	10	0
Russia in Europe ..	1,862,504	61,175,923	32·85	48,952,699	0	16	0
British India	983,902	148,457,651	150·89	86,567,116	0	11	7¾

"From the foregoing it will be readily seen how poor India really is when compared with other countries. This is no doubt in a great measure due to the fact of its being essentially an agricultural country, manufactures holding but a small place in the list of her exports. Whatever may be the cause of her poverty, however—a question which it would be beside our present object to stop to inquire into—it is clear, from what we have already shown, that India not only does not require, but that her actual means are not such as to justify, nor her trade such as to demand, at least in the present generation, such a system of railways as wealthier and more fully developed countries can afford to indulge in.

"The question of passenger traffic may be more briefly disposed of than that of goods traffic, which we have just been considering, and in this case it will not be necessary to resort to comparison with similar traffic on the lines of other countries, as the main point is dependent not so much upon the numbers to be carried, as upon the capabilities of a narrow 2 ft. 9 in. line to accommodate passenger traffic. Goods and third-class passengers constitute the principal portion of existing Indian railway traffic, and, excepting that first and second class passengers require to be provided with travelling accommodation, they might almost have been left out of the question in consideration of this subject. Few as the superior class of passengers are upon existing lines, they will probably be still fewer upon the strictly commercial lines which will constitute this secondary and narrower system of Indian railways now proposed to be laid; still, however, in taking a comprehensive view of the requirements of the country, it would not do to leave these out of consideration altogether.

"During the year 1869 there travelled upon the combined Indian railways 16,011,633 passengers, of whom 137,762 were first, 626,355 second, and 15,247,516 third class, the last being 95·23 per cent. of the whole. The receipts from passengers amounted to 1,496,117*l.*, of which 1,263,481*l.*, or 84·45 per cent. was obtained from the third class, the second class producing 133,773*l.*, and the first 92,000*l.* The number of passenger trains run during the same period was 18,404, and of mixed passenger and goods trains 45,296, making a total of 63,700 trains by which passengers were conveyed, and which travelled together 6,600,478

miles. The length of railway opened being, as before stated, 4965 miles, we deduce the following facts as regards passenger traffic. The number of passengers of all classes per mile of railway open was 3939, or about 10·75 per mile per diem, supposing the traffic to be equally conducted during the whole 365 days in the year, whilst the total number carried per train mile was barely 2·5. We have not the means at hand to compare the foregoing figures in all respects with similar figures relating to lines in the United Kingdom, but we do possess such means as will enable a comparison to be drawn between the numbers carried per mile of railway open, which, therefore, for greater convenience of reference, we repeat in the following tabulated form:—

	Length Open.	Total Number of Passengers carried.	Number of Passengers carried per Mile of Line Open.
United Kingdom ..	14,247	287,807,904	20,201
Festiniog Railway ..	14·00	97,000	6,807
Indian Railways ..	4,065	16,011,633	3,939

"Arguing from the foregoing figures, and from the conclusions presented in the previous statements regarding the existing goods traffic on Indian lines, it would appear that a system of railways laid upon the narrow gauge of the Festiniog line would have been amply sufficient to meet all the requirements of Indian traffic; at least the average work done by the former during the year 1869 was considerably less in all respects than that performed by the latter. No doubt with the narrow gauge, supposing that had been adopted for India, difficulties would have at times been experienced in accommodating the traffic, especially for passengers during the Mahomedan festivals, and for goods after the period of gathering the cotton crops; these, however, represent the exceptional circumstances of ordinary traffic which render necessary some greater width of gauge, and consequent greater capabilities for traffic, than could be afforded by so narrow a gauge as that with which we have drawn a comparison.

"In order to arrive at some estimate as to the requirements for accommodation for passengers of the different classes in India, with a view to calculating the necessary dimensions and amount of rolling stock for Indian lines, some further subdivision of the

traffic on existing lines is necessary, which will tend to throw more light upon the subject than could be afforded by any amount of empirical assertions. Indeed, to provide accommodation for the passenger traffic of the proposed secondary system of railways in India, based upon the actual traffic of the existing main lines, could scarcely fail to be much in excess of the real requirements of such lines. In an argument such as that which we are now involved in, however, it is always safer to allow wider margins than would be permitted in practice, and for that purpose we adopt what may well be considered as a maximum standard of comparison. It has been stated above that (omitting fractions) 3939 passengers were carried on the Indian railways, in 1869, per mile of line open, and the total carried per train mile was 2·5. Of these there travelled, of first-class passengers, 34 per mile of line open, of second class 154, and of third class 3751; or, for every first-class passenger carried per mile, there were 4½ second class, and 110 third class. Hence we arrive at such facts as will enable us to draw some conclusions as to the character and amount of passenger rolling stock. For third-class passengers the carriages might be 5 ft. wide inside, with cross seats, holding three passengers on each seat. This would give 1 ft. 8 in. in width for each seat, and carriages 16 ft. long, inside measurement, would accommodate 18 passengers each, allowing 18 in. width for the seats, and a space of 2 ft. between them. Although each line might require some few first-class carriages capable of holding several passengers, it would probably be most economical to make most of the first and second class composite carriages. These should not be less than 6 ft. wide, inside measurement, with which dimensions, if fitted with cross seats, each passenger would have a seat of fully 2 ft. in width, or more than is often given to first-class passengers on railways in England. It is, however, a question whether the accommodation might not be more conveniently afforded by making the first and second class carriages with longitudinal seats like omnibuses, on which form some of the carriages belonging to the Queensland Railway have been constructed. That a width of 6 ft. 6 in. may safely be given to passenger carriages on a 2 ft. 9 in. railway there can be no doubt, as some of those on the much narrower Festiniog line are as wide as 6 ft. 3 in. By increasing the width of gauge to 3 ft. 6 in. it

would be impossible to provide accommodation in the carriages for an increased number of passengers, giving each the amount of space above mentioned, without altering the proportion between the total width of carriage to the gauge. In the third-class carriages above referred to the extreme width is double that of the gauge; to provide accommodation for an extra seat in width on the 3 ft. 6 in. gauge would require that the carriages should be only 4 in. in excess of twice the gauge; but with first and second class stock, with seats 2 ft. in width, the carriages must be 18 in. wider than twice the gauge with one of 3 ft. 6 in., whilst it need only exceed it by 12 in. with the 2 ft. 9 in. gauge. We do not mean to contend for one moment that this slight difference would materially affect the safety or steadiness of the carriages; but in the face of the statistics of Indian railway traffic, which have been given above, it would be difficult to find arguments in favour of carriages having any greater amount of accommodation than can be provided to run safely upon a 2 ft. 9 in. railway. To reason that with a development of the country's resources the demands for traffic will increase, would be insufficient to prove that a 2 ft. 9 in. railway will not long be able to meet the requirements for passenger traffic. The East Indian Railway, if laid with a gauge of only 2 ft. in width, might easily carry the whole of its present traffic if it were only provided with a sufficient amount of locomotives and rolling stock. Indeed, the question of traffic on Indian lines depends more upon the rolling stock than upon the gauge, a narrower gauge probably demanding a greater number of trains per day, and consequently a proportionally heavier rail section than would be due merely to the difference in weight per wheel of the heaviest rolling stock or locomotives in use upon it.

"Having dwelt at some length upon the goods and passenger traffic, we have now to approach the more difficult subject for narrow gauge lines of horse and cattle traffic; and here it must be admitted that a 2 ft. 9 in. gauge would not be so advantageous as a broader one. It is not our purpose to stop and consider how horse boxes or cattle trucks could best be constructed for so narrow a gauge, but rather to consider what demands exist for the provision of accommodation for such traffic. On this branch of the subject it is evidently unnecessary to take into consideration

any account of sheep, pigs, dogs, and other small live stock, for which trucks could be readily provided upon a line of any width. With regard to horses and cattle we have accurate statistics from which to draw our calculations, from which it appears that during the year there were 23,194 of the former, and 6988 of the latter. Taking the mileage, as before, at 4065 miles of line open, the amount of horse traffic amounted only to about 5·7 per mile per annum, and of cattle to 1·7 per mile per annum, whilst the total receipts for the conveyance of live stock of every description during the year amounted only to 18,693*l*. Under these circumstances it would clearly be more reasonable to adapt special trucks to the narrower gauge for the conveyance of the larger class of live stock, than to construct the railways of a greater width, and at an increased cost, in order to accommodate the line to the rolling stock for so very insignificant an amount of traffic. From whatever point we view this question of gauge, in reference to the actual requirements of the country, and the capabilities of the rolling stock to fulfil the necessities of the traffic for which they will be constructed, and by means of which they may be expected to prove remunerative, the one prominent fact appears, that upon no line that may be made and classed as a secondary line of communication is there likely to be, for many a long year to come, sufficient traffic fully to occupy so small a line as that from Portmadoc to Festiniog. In order, however, to make provision for the emergencies of extra traffic which may often occur in India, and to meet the special requirements of traffic and other circumstances which are due to the peculiarities of the country and climate, a somewhat broader gauge is indispensable. From a commercial point of view, and regarding railways merely as vehicles for the conveyance of passengers and ordinary goods, it is clear that such lines as those to which our arguments refer should be made with the narrowest possible gauge, and upon the lightest and cheapest principles consistent with true working efficiency and economy of maintenance."

I observe it is stated in Mr. Juland Danvers' report on railways in India for the year 1869–70 (a matter which might lead to misapprehension) that I am an advocate for "light and narrow gauge railways." I certainly advocate narrow gauge railways, but not what is termed "light railways," or lines on the usual or

standard gauge, of a lighter character with lighter permanent way, lighter engines, and lighter rolling stock.

Railways of this last-named description would have the same earthworks as the existing system, and it is evident that the locomotive and rolling stock must be made in suitable proportion for the gauge. The dimensions of an engine must in every respect be the same as the ordinary locomotive, excepting that its parts would be made lighter, by reducing the thickness of boiler-plates, fire-box, &c.; hence it is obvious that locomotives of this description must be worked at a low pressure, though I presume it is intended with "light railways" to use 4 ft. or 4 ft. 6 in. driving wheels, and smaller boilers, and fire-box of ordinary strength and thickness (or nearly so), that a high pressure may be obtained when needed. Well, admitted that all this can be done; but the adoption of the system will be going back to the old days of first locomotives of 12 to 16 tons in weight; but it may be said that little matters, however inconsistent, so that the object is attained. Such engines, however, would take but a very small paying load on account of the great weight of rolling stock.

A four-wheel engine on 2 ft. 9 in. gauge will take the same paying load with less dead weight of trains of 27 per cent., or with an annual traffic of 250,000 tons of minerals and goods, there would be a saving of 41,600 tons of dead weight hauled—or supposing the load of each train at 100 tons, would give 416 trains less run in performing the above traffic.

Then, as to the carriages and trucks, it is stated by some eminent engineers that the object of light railways is that the rolling stock of the other lines (or what may be termed railways proper) may run over the light lines, and that of the light lines in like manner used on the railways proper. If such is the case, what would be the advantage of constructing light rolling stock for the light lines? and the question arises as to the applicability of the interchange of the different kind of rolling stock on the two systems.

If the light trucks were used in combination with the other, the wear and tear on them would undoubtedly be very great. In regard to the heavy rolling stock at present in use on the Indian lines, I find there are cotton trucks of 24 feet in length, to buffer beam 9 ft. 9 in. wide and 8 ft. deep, with tare weight of 6 tons

5 cwt. *Coal trucks*, 17 ft. long, to buffer beam 8 ft. $4\frac{3}{4}$ in. wide, and tare weight 6 tons, to carry 12 tons or $4\frac{1}{2}$ tons to a wheel. *Trucks* for carrying iron bars, or ordnance and other heavy materials, of 19 ft. 10 in. long, to buffer beam 9 ft. wide, and carrying 15 tons, with tare weight of 7 tons or $5\frac{1}{2}$ tons on a wheel, besides other trucks of more or less weight and carrying capacity. These weights are clearly out of proportion for a 75-lb. rail, and consequently more so for a 45-lb. rail proposed for the light Indian railways. It has been proved by experience on the Festiniog Railway that a rail of 30 lbs. to the yard will not bear the weight of locomotive of $2\frac{1}{2}$ tons on each wheel even with sleepers having bearings of 2 ft. 6 in. and 1 ft. 6 in. centres at joint, and the $48\frac{1}{2}$-lb. rails now in use are not at all too strong. There is no doubt that for a weight of 3 tons per wheel, a rail of not less than 55 lbs. per yard should be used, and for 4 tons per wheel, the rail should weigh at the least 65 lbs. per yard to ensure stability and fair wear and economy in maintenance of way. Then, again, can it always be secured that locomotives of the ordinary lines are not allowed to run over the light lines? I think not. It stands to reason, therefore, that the light system, so far as rolling stock is concerned, must have as strong a permanent way as that of the ordinary lines. As this is so, where does the peculiar advantage of light railways on the ordinary gauge exist? It will appear there can be none; and that their adoption would be fallacious in the extreme, and can only lead to confusion and unnecessary expenditure. If an uniformity of the present gauge must be maintained, then that expensive and ruinous system will be kept up in all future time and development. It is very desirable that the wide-spread districts of the Russian, Indian, and Colonial territories not possessing the advantages of railway communication be opened up, but it is out of the question to effect this, however urgent, on the present expensive system of 5 ft. and 5 ft. 6 in. gauge with any prospect of remunerative success. I understand it is contemplated to construct from 5000 to 10,000 miles of new lines in India. It must be admitted by all interested in railways in the above-named countries, that the result of the system as carried out is very unsatisfactory. The reason of this is because, in the first place, the capital outlay is totally out of proportion to the traffic, or any anticipated traffic, that can be

secured. In the second place the maintenance and renewal of permanent way is heavy by reason of the instability of the way, the strength of the rails not being compatible to the weight brought upon them. Directors and engineers have tried in vain to lessen the ruinous expenditure, and often fall into error by reducing the weight of rails, thus rendering the evil greater than before. The importance of this subject will be seen when it is considered that the annual cost of maintenance and renewal of permanent way on railways in this country are more than $10\frac{1}{4}$ per cent. of the gross receipts, and on Indian lines $14\frac{1}{4}$ per cent., and that it forms 19 per cent. of the working expenses, while the repairs and renewals of carriages and trucks is over 8 per cent. This latter cost to a great extent depends on the state of the permanent way. To reduce this heavy expenditure, the load should be *dispersed* over *a greater length of line*, so that the rails be fairly worn, and the iron not disintegrated by the superincumbent weight and impact force it has to sustain.

The following would be suitable weights and dimensions for locomotives and rolling stock for 2 ft. 9 in. gauge:—

Double bogie locomotive, 8 wheels, from 20 to 24 tons in weight.

Four-wheel engines for shunting 10 to 12 tons in steam.

Cotton truck, 16 ft. long, 6 ft. 2 in. wide, outside measurement, and 4 ft. 5 in. deep, 8 ft. 6 in. wheel base, tare weight 2 tons 15 cwt. to 3 tons, and carry $3\frac{1}{4}$ tons of screwed cotton.

Cotton truck on two bogies, 35 ft. long, 5 ft. 9 in. wide, and 6 ft. deep (between bogie frames), tare weight 5 tons 6 cwt., and carry 9 tons.

Coal truck, 12 ft. 4 in. long, 6 ft. 2 in. wide, and 4 ft. 1 in. deep, with 6 ft. 10 in. wheel base, tare weight 2 tons; to carry 6 tons. Other goods trucks 2 ft., and 2 ft. 6 in. deep, to carry 10 to 12 tons of iron ordnance, or other heavy material.

Coal truck on two bogies, 26 ft. long, 5 ft. 9 in. wide, and 4 ft. 6 in. deep (between bogie frames), to carry 13 tons, the weight of trucks $4\frac{1}{2}$ tons. Timber bogie trucks of 32 cwt., and 2 tons 8 cwt. the pair respectively, to carry 8 to 14 tons of timber.

Bogie ordnance truck (12 wheels), weight, 5 tons 15 cwt., to carry 24-ton passenger carriages 12 ft. 6 in. long, 6 ft. 2 in. wide,

with 7 ft. 6 in. wheel base, two compartments to carry 12 first-class passengers; seat room 23 in. to each person.

Third-class to carry 16 persons, with $17\frac{1}{4}$ in. seat room for each passenger.

First-class bogie passenger carriage, 46 ft. 6 in. long over buffers, 6 ft. 2 in. wide, with 5 compartments and van to carry 30 persons; tare weight 7 tons 10 cwt., with gross load $9\frac{1}{2}$ tons, or nearly $1\frac{1}{4}$ ton on a wheel.

Third-class passenger bogie carriage of $45\frac{1}{4}$ ft. long, with 7 compartments and van to carry 56 persons.

Night trains—and for long journeys the first-class compartments with turn-up arm-rests should only carry 4 persons in each compartment—with seat room of $34\frac{1}{2}$ in., and second-class compartments for 6 passengers, with seat room of 23 in. to each.

There has been much said and written as to whether the rolling stock of a line should be guided by the gauge, or the gauge by the rolling stock. I maintain that if a certain gauge is adopted, the rolling stock should be proportionate, or in constants and compatible with such gauge. The question then arises, what are the correct or suitable proportions? For four-wheel carriages there should be the right wheel base width and lengths applied, according to the maximum curves of line. Some engineers fix the wheel base at twice the gauge, the width nearly twice the gauge, and length three times the gauge, outside dimensions. (How is it that the wheel base of ordinary passenger carriages is frequently put at 14, 15, and 18-feet centres; therefore why not make goods trucks with centre wheel base and proportionate lengths?) It must be admitted that the ordinary rolling stock is made to carry less than it should do, and certainly it is clear that the advantage offered by gauge to carry the greatest bulk or weight on four wheels is not made use of. Why is this so? It will appear that the simple reason is that it would incur *too great a weight on permanent way*, and therefore it is not applied, and if applied, would necessitate a greater width of works; these are two of the many tangible reasons, and must stand as evidence against the broader gauges.

On the Festiniog Railway the proportions of rolling stock to gauge are, wheel base of passenger carriage, $2\frac{3}{4}$ times the gauge, nearly; width, $2\frac{1}{2}$; and length, 5 times the gauge. Coal trucks,

COMPARATIVE TABLE of DIMENSIONS of COAL TRUCKS in PROPORTION to GAUGE.

	Gauge.	Maximum Wheel Base.	Length.	Width.	Depth.	Height of Floor above Rails.	Tare Weight.	Load of Coals 43 cubic feet to a ton.	Gross Weight.	Weight to each Wheel.	Angle of Stability.	Usual Load of Truck at present in use.	Floor Area.	Equivalent Curves.	Equivalent Weights for Rail.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	t. c.	t. c.	t. c.	t. c.		tons.	sq. ft.	ch. links.	lbs.
Festiniog Railway	1 11½	5 6	9 6	4 10	3 5	1 10	0 19	2 16	3 15	0 18¾	39°	3	37	1 75	48½
Ditto revised Proportions ..	1 11½	4 10	8 10	4 5	2 11	1 7	0 13	2 0	2 13	0 13	..	..	31	2 45	48½
	2 6	6 3	11 3	5 7	3 9	2 1	1 10	4 10	6 0	1 9	..	..	54	4 0	55
	2 9	6 10	12 4	6 2	4 1	2 4	2 0	6 0	8 0	2 0	.. 42½°	..	65	4 84	58
	3 6	8 9	15 9	7 10	5 3	3 2	4 0	12 0	16 0	4 0	..	5 to 6	104	7 84	70
	4 8½	11 9	21 2	10 7	7 0	4 2	10 6	31 0	41 6	10 1	..	8 to 10	202	14 16	104
	5 6	13 9	24 9	12 4	8 3	4 9	16 0	48 0	64 0	16 0	..	10 to 12	260	19 36	130

From the above data this Table shows that 3 ft. 6 in., 4 ft. 8½ in.. and 5 ft. 6 in. gauges are totally inapplicable, as there would be too great a weight on each wheel.

the wheel base nearly 3 times; width, $2\frac{1}{2}$; length, $4\frac{3}{4}$; and depth, $1\frac{3}{4}$ times the gauge, outside dimensions. No doubt a modification of these extreme dimensions is desirable for 2 ft. 9 in. gauge when higher velocities than 20 miles an hour working speed of mineral trains is intended. Say for coal trucks the wheel base to be $2\frac{1}{2}$ the gauge; the width, $2\frac{1}{4}$; length, $4\frac{1}{2}$; and depth, $1\frac{1}{2}$ times the gauge. On this basis the dimensions and carrying capacity, &c., for different gauges will be as per foregoing table.

I observe in the Tables of Traffic in the before-named report on Indian railways, that the East Indian (main line), which has the largest traffic in India, carried for the year ended 31st December, 1869, 4,910,417$\frac{1}{2}$ passengers, and 1,223,740 tons of goods and minerals on the number of miles opened of 206 double and 1132 single, or total single miles of 1338, which gives 3670 passengers and 914 tons per mile respectively, having 1 locomotive for every 2·68 miles. On the Festiniog Railway (single line) of only 1 ft. 11$\frac{1}{2}$ in. gauge, the passenger traffic per mile in the same year was 7444, and of minerals and merchandise 10,180 tons per mile of line, having 1 engine for every 2 miles of railway.

The following comparative table shows the capital cost, traffic receipts, working expenses and receipts per mile of some of the home, foreign, and colonial railways.

If all the locomotives on the Festiniog Railway for working the traffic were double bogie Fairlie engines, more than twice the traffic could be performed than if all the engines were of the ordinary type on four wheels, such as the "Pony" and "Little Giant"; or that less than half the number of long trains worked by bogie engines would perform the traffic in the same time, as engine against engine.

The question arises, if so much work can be done under various peculiar difficulties as with this line for working the traffic, and upon so narrow a gauge as only 1 ft. 11$\frac{1}{2}$ in., and at so small a capital cost, why make broad gauge railways at a heavy outlay to carry so small a traffic as that of the Indian, Russian, and Irish lines?

The other objection besides break of gauge that has been brought forward against the narrow gauge is, that the speed is not equal to what can be attained on the broad gauge. This is

COMPARATIVE TABLE of CAPITAL, RECEIPTS, EXPENDITURE, &c., of HOME and COLONIAL RAILWAYS.

	For the Year ending	Length. Miles reduced to Single Line.	Capital Cost per Mile, including Rolling Stock and Works.	Number of Locomotives per Mile.	Coaching per Mile.	Merchandise and Mineral Trucks per Mile.	Number of Passengers carried per Mile.	Number of Tons of Minerals and Goods per Mile.	Receipts per Mile.	Cost of Maintenance and Renewal of Permanent Way and Works per Train Mile.	Locomotive Expenses per Train Mile.	Cost of Repairs and Renewals of Rolling Stock per Train Mile.	Traffic Charges per Train Mile.	Maintenance and Renewal of Works per ton carried, including Passengers and Luggage.	Locomotive Expenses per ton carried, including Passengers and Luggage.	Repairs and Renewals of Rolling Stock per the ton carried, including Passengers and Luggage.	Traffic Charge per ton carried, including Passengers and Luggage.
			£.					tons.	£.	d.	d.	d.	d.	d.	d.	d.	d.
London and North-Western	Dec., 1868	2414	21,786	·63	1·1	10·9	11,389	6,665	2810	5·50	8·47	2·73	10·58	6·51	10·02	3·23	12·52
Great Western	" "	2233	20,935	·38	1·2	7·5	10,436	3,626	1788	6·59	7·93	3·05	9·19	8·60	10·35	3·98	12·00
Great Northern	" "	947	19,444	·53	1·4	11·2	9,094	4,570	2270	5·53	9·01	2·48	8·04	9·30	15·12	4·18	13·51
North-Eastern	" "	2030	19,470	·42	1·0	30·0	6,985	10,310	1908	6·12	10·20	4·74	6·40	3·76	6·59	2·91	3·94
Great Eastern	" "	1220	20,820	·34	1·4	8·0	14,884	2,602	1756	6·29	9·48	2·99	11·23	8·52	12·82	4·05	12·66
London and Brighton	" "	615	29,784	·41	3·0	6·3	28,486	2,063	2064	6·45	11·11	2·75	10·93	8·55	14·72	3·64	14·48
South-Eastern	Jan., 1869	611	30,295	·39	3·1	5·7	31,991	1,607	2490	6·88	8·94	2·52	11·34	9·92	12·88	3·64	16·34
Cambrian	Dec., 1868	185	18,692	·21	·57	6·6	5,366	1,820	802	9·81	5·90	2·65	8·33	15·41	9·28	4·17	13·10
Caledonian	Jan., 1869	1141	19,078	·45	1·0	12·8	8,118	7,266	1652	6·01	8·06	1·88	7·04	5·11	6·86	1·60	6·00
North British	" "	1144	16,678	·34	1·0	12·6	7,257	5,400	1330	7·41	6·84	3·32	8·48	6·61	6·10	2·96	7·05
Highland	Feb., 1869	275	11,435	·20	·67	4·4	3,323	952	788	3·70	6·32	2·30	8·71	9·48	16·14	5·88	22·25
Great Southern and Western	June, 1870	632	9,866	·19	·58	3·1	2,716	830	868	8·13	9·91	2·08	7·23	18·90	23·49	4·84	16·83
Dublin and Drogheda	Dec., 1868	107	11,080	·20	1·1	2·4	7,976	886	949	6·72	7·56	2·20	6·08	14·47	16·20	4·73	13·08
Grand Trunk of Canada	June, 1870	1377	13,511	·23	·27	2·9	506	445	511	11·34	15·17	5·22	12·97	22·18	61·08	21·00	52·20
East Indian and Jubbulpore	Dec., 1869	1561	19,216	·34	·57	4·2	3,249	832	1615	10·27	26·20	3·78	8·30	28·03	61·84	13·88	32·99
Bombay and Baroda	" "	326	22,603	·20	·56	8·8	5,666	556	1344	20·06	24·71	11·09	5·73	47·00	57·90	26·00	26·85
Eastern Bengal	" "	113	24,355	·38	1·1	5·7	11,372	1,551	1433	12·13	15·43	2·55	8·03	15·65	19·92	3·29	20·72
Festiniog	" "	14	{5378, 2000} =7378 Rolling Stock. Cost of Line includes two renewals of Permanent Way, and reconstruction of considerable portions of Line for Passenger Railway, including half a mile of Tunnel, Foundry, Workshops, and Wharves.	·42	1·0 Including Workmen's Carriages, 3·2	63·7	6,637	9,053	1561	4·91	5·35	3·60	10·39	3·24	3·54	2·38	6·87 Which includes 2¼d. tonnages to estates.

true; however, it has been proved that a speed of 30 miles an hour can be run with ease and safety on the Festiniog line. It appears from Appendix B of the before-named report on railways in India, that the proposed State railways on 5 ft. 6 in. gauge in that country are to be designed and constructed for a traffic worked at a speed of 15 miles an hour; it is therefore apparent that these at least could not claim any superiority over a narrow gauge.

I can only repeat my conviction, as represented in my paper read at the Inventors' Institute six years since, that the more this subject is considered and its merits discussed, the greater will appear the advantages of the narrow system, and the benefits derivable by introduction of small gauge railways in all countries of the globe.

Portmadoc, North Wales,
November, 1870.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.